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USEPE

U-SPACE SEPARATION IN EUROPE

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Abstract

This document represents the Final Project Results Report of the USEPE project. This deliverable contains the project overview, the summary of work performed and key project results, and a description of technical deliverables. The link to the SESAR programme is given by the identification of the project's contribution to the ATM Master Plan [38] and a maturity assessment for U-space service V1. Finally, conclusions and recommendations for clarification, standardisation and regulation, and for further R&D needs are summarized. The present version is a draft but consolidated version for the SJU to have the project's results in advance the Final Maturity Gate. The final version will be delivered in December after the Final Maturity Gate Meeting and will include the comments received from the SJU.

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1 Executive Summary

This document represents the USEPE Final Project Results Report (in draft version before the Final Maturity Gate), which summarises the main findings obtained during the development of the USEPE project. The main goal of the project was to develop a new and safe separation method for Unmanned Aircraft System (UAS) flying in high density populated environments. To this end, the Dynamic Density Corridor Concept (D2-C2) has been described and validated throughout the project. In order to give a brief overview of USEPE results, this report is focused on different aspects detailed below.

Firstly, in an overview chapter, the context of the project is defined, and the scope and the four project objectives are described. The work performed in the technical work packages for the separation concept, the development of design concept and the simulation and validation is elaborated. Afterwards, the key project results are presented by a summary of the stakeholders' needs and requirements, the D2-C2 method, the system requirements, the validation results and the Machine Learning (ML) achievements. The list and short description of the technical deliverables from the project concludes the overview chapter.

In a second phase, the summary of the communication and dissemination activities carried out during the USEPE project is listed, including the three high-level key messages of the USEPE project.

Thereafter, links to the SESAR Programme are given by a description of the contribution to the ATM Master Plan [38] and a Maturity Assessment for U-space service V1 maturity (for the strategic and tactical deconfliction services). Most criteria have been achieved, with only a small number of 'Not achieved/Partially achieved' criteria. The number of criteria with status 'Achieved' is highest, with one criterion not applicable in this context, and three criteria with status 'Not achieved' in each service. For this reason, the overall USEPE Solution is expected to be a V1/TRL-2 solution.

As a last phase, conclusions and recommendations of the presented results are drawn. USEPE has provided conclusions on the maturity of the USEPE Solution and supporting services, in particular, strategic and tactical conflict resolution services, on technical design, feasibility and architecture, on performance and benefit assessment and on the system requirements. Further, recommendations regarding the concept clarification, standardisation and regulation, and the R&D needs are provided based on the outputs of USEPE. An outlook is given for the next research and development phase regarding full city-wide simulation based on D2-C2 method, further R&D activities for USEPE V1 maturity and future potential contribution to SESAR Programme.

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2 Project Overview

The USEPE project has defined and validated a new separation method, named D2-C2, to be used in high densely populated environments in a U-space context. The following sections describe the context in which USEPE project is placed, the project scope and objectives and the work performed in the technical work packages. Further, the key project results are presented and a list with all technical deliverables is provided.

2.1 Operational/Technical Context

The number of drones' applications is increasing and, with them, the number of simultaneous drone operations in the same geographical area. Drones will need to be safely separated between them, from buildings and from manned aircraft. Mapping, infrastructure inspections, precision agriculture, etc. are just some of the potential services that can be delivered using drones. New use cases, together with the expected higher number of drones, confront stakeholders with new challenges in terms of strategic planning, regulatory and operational issues.

USEPE targets the identification of separation methods applicable to the safe separation of drones between themselves and other aircraft flying at Very Low Level (VLL) in densely populated environments under a U-space concept. USEPE proposes to extend the usable U-space airspace over urban environments to 900 ft Above Ground Level (AGL), leaving 100 ft as a buffer for possible navigation errors, where no manned flights should be taking place in nominal conditions (except those specifically intended by police and emergency). To this end, the operational environments foreseen for drones' operations are the air and ground environments that comprise high densely populated areas, i.e., urban or suburban environments.

In order to identify the constraints imposed to USEPE by previous regulatory and U-space work, it is relevant to characterise EASA drone categories and CORUS airspace volumes.

CORUS[1] [39] defines three different airspace volumes: X, Y, Z showed in Table 1.

Table 1. CORUS Airspace volumes

X	Y	Z
Low demand, low risk	Higher risk than X, approved operation plan	Higher density than Y, or a particular risk
No conflict resolution	Strategical resolution	Strategical and tactical resolution

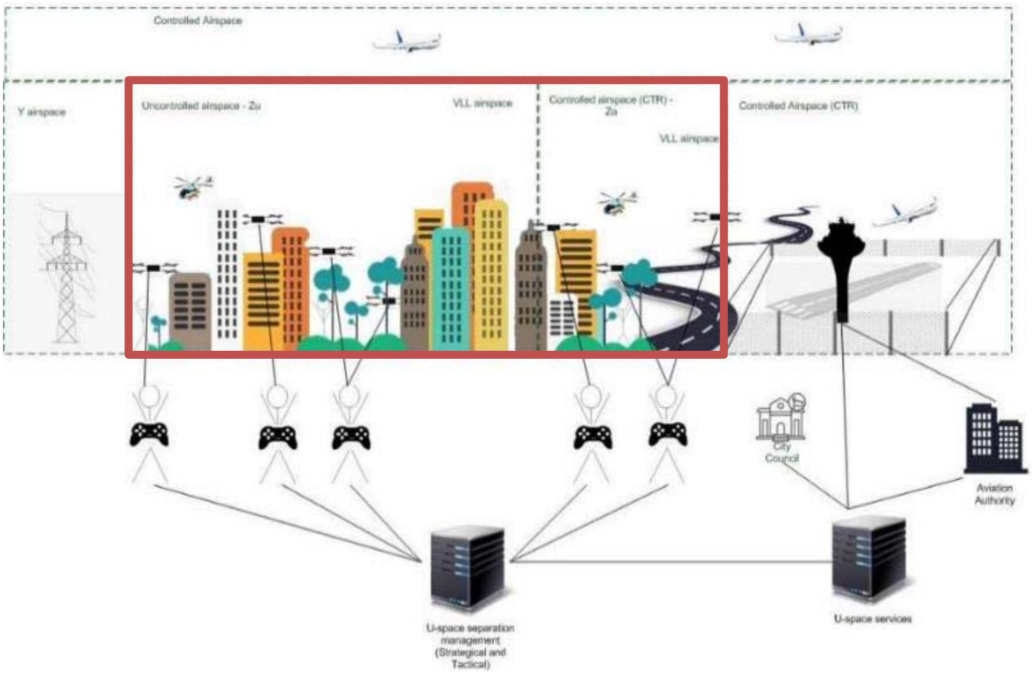
The Z airspace volume has the higher air and ground risks and it is the most favourable airspace for densely populated environments. Moreover, considers the conflict resolution at strategic and tactical levels and environments where Air Traffic Services (ATS) are provided. It can be concluded that USEPE

[1] CORUS-XUAM D4.1 U-space ConOps (edition 4) is being prepared at the time of drafting this document. In edition 4 there is a new sub-volume within Volume Z: Zz. This document does not refer to that new definition.

will consider Z (Zu and Za) airspace volumes and will be the ones that are imposing operational limitations.

In Figure 1 the USEPE operational environment is represented together with its lateral and vertical limits highlighted by a red line.

Figure 1. USEPE operational environment



Regarding the drones' categories, EASA regulation 2019/947 [40] defines these categories according to their operations. Specifically, three different categories are considered: 'Open', 'Specific' and 'Certified'.

- In the 'Open' category, the pilot flies under Visual line-of-sight (VLOS) and is responsible for separation, so it falls out of the USEPE scope as no separation service will be provided by U-space.
- In the 'Specific' category, flights can take place in Y and Z airspace volumes. Since USEPE addresses the Z volume, this category is relevant for the project and imposes operational limitations.
- Although the same occurs with the 'Certified' category, the performance of drones may be excessive for a densely populated urban environment, i.e., drones need to be certified due to the high risk for safety and it is very unlikely that in a densely populated area a 'Certified' category drone will fly for any specific purpose.

To this end, USEPE project focuses on **airspace volume Z, either Zu or Za** with drones under the **'Specific' category**.

The focus of USEPE is on the separation topic. USEPE with its new separation method (D2-C2), contributes to the provision of **strategic and tactical conflict resolution services**. This method considers the U-Space Service Providers (USSPs), through the provision of strategic and tactical conflict resolution, an important piece for separation management.

A summary of the USEPE operational and technical context (the airspace volume and drone category addressed by the project), and its main contribution to U-space services is summarized in Table 2. It is worth mentioning that although only the strategic and tactical conflict resolution services are reflected in the table, there is still a strong interaction with the rest of the U-space services (e.g., tracking, weather information service, operation plan processing, etc.).

Table 2. Summary of USEPE operational/technical context

Airspace volume addressed by USEPE	**Volume Z** ▪ Areas where there is a significant demand of U-space services, exceeding Y airspace demand ▪ Over densely populated areas ▪ VLOS and BVLOS flights ▪ Pre-flight (strategical) deconfliction and during flight (tactical) deconfliction Divided into: • **Zu**: Conflict resolution provided by U-space services • **Za:** Conflict resolution provided by ATS (VLL airspace controlled by ATS, e.g., Controlled Traffic Region (CTR))
Drone category addressed by USEPE	**'Specific'** ▪ Drone operators are required to ask for an authorisation to the National Competent Authority or its delegates ▪ Required to submit an operations plan ▪ Authorisation not necessary if the flight falls under one Standard Scenario (EASA)
Contribution to U-space services	**Strategic Conflict Resolution** **Tactical Conflict Resolution**

2.2 Project Scope and Objectives

The goal of USEPE is to propose, develop and evaluate a Concept of Operations (ConOps) and a set of enabling technologies aimed at ensuring the safe separation of drones (from each other and from manned aviation) in the U-space environment, with particular focus on densely populated areas. In order to achieve this goal, four specific objectives were identified:

Objective #1: Identify who shall be the predetermined separator (the drones themselves or the U-space systems) throughout the strategic and tactical planning phases.

USEPE proposes a new separation method, the D2-C2, which considers the paramount role of the USSP, through the provision of strategic and tactical conflict resolution. From the survey and initial workshop organised by USEPE, it was made clear to the Consortium that stakeholders were in favour of the USSP providing the separation between drones (when flying in Zu airspace volume).

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USSP will play one of the major roles in the separation management and provision of drones at very low altitude in U-space airspace. In the D2-C2 method, they are in the centre of the operation and have the capability to define different airspace structures outside the drone corridors, using the geovectoring syntax, as well as stablishing corridors and dynamic segments.

Before the flight, in a strategic layer, the USSP receives the different flight plans from the drone operators. After the analysis and verification, the USSP optimizes the trajectories and if any modification is proposed, the USSP will ask for agreement with the drone operator.

During the flight, in a tactical layer, drones communicate their speed and position to the USSP through the traffic and position reporting service. USSP is in charge of communicating possible dynamic changes in capacity and geo-vectors. USSP could request the drone operators to perform corrective actions. The operator of the drone receives the command and is responsible of performing the suggested manoeuvre.

The responsibilities are comparable to manned aviation: U-space tactical deconfliction helps in the separation of UAS, just like Air Traffic Control (ATC) serves this purpose for manned aviation. While pilots are strongly bound to the advice of ATC, ultimately the pilot remains responsible for their own aircraft. This principle still applies in USEPE, where a pilot will act according to U-space directions but still has to ensure safety.

In short, USEPE creates a new separation method, the D2-C2, where the main separator is finally the USSP, during both the strategic and tactical phases, but the operator is still responsible for its own aircraft.

Objective #2: Define and simulate a set of concepts to provide safe separation for different kind of drones in each planning phase. This will include concepts such as density-based separation and geo-vectoring, as well as exploring how artificial intelligence and machine learning algorithms can enhance these concepts.

The new separation method proposed by USEPE, which combines dynamic segments, corridors and geo-vectoring syntaxes is simulated in an open-source environment, BlueSky. Three different exercises (last mile delivery, emergency situation and urban surveillance) were considered during the simulation campaign in nominal and contingency situations and compared to a reference scenario where the D2-C2 method was not applied. Both the strategic and tactical layers of deconfliction were taken into account during the simulations.

Further, an exploration of how Artificial Intelligence (AI) can enhance this concept was done through WP4. An unsupervised Machine Learning algorithm (USEPE_ML) was developed to support D2-C2 implementation such as route planning and dynamic segmentation. It has been validated using some Key Performance Indicators (KPIs) such as the number of conflicts. Therefore, the USEPE_ML provides quantitative information for automation to be used by an AI agent.

Objective #3: Assess the impact of the proposed concepts on different Key Performance Areas (KPAs), in particular on safety, capacity and efficiency, in order to derive conclusions and recommendations on the most adequate approach for each operational environment.

The USEPE Validation Plan [15] set 18 high-level validation objectives, to assess the USEPE solution with reference to the SESAR KPAs: Safety, Capacity and Operational Efficiency.

Safety has played a central role in the validation objectives since the ultimate goal of the USEPE project is to ensure the safe separation between drones in urban environments taking into account weather or obstacles. Operational and capacity metrics have been optimised, when possible, always maintaining minimum safety levels. The validation results regarding this KPA's are further described in D5.2 USEPE Exploratory Research Validation Report [16].

Based on the scenarios described in D3.2 USEPE Initial Concept of Operations [11], three different validation exercises have been selected: last mile delivery, emergency situation and urban surveillance, sufficient to successfully achieve the maturity level for the SESAR SOL-USEPE under its scope.

For all three exercises, the Validation Plan specified the validation technique - fast time simulations - the platform used, BlueSky, the Open-Air Traffic Simulator, the information related to the expected data, the data collection method and the data analysis. Further, weather considerations (e.g., a convective condition) were used in the atmospheric flow simulations with the PALM tool.

Objective #4: Disseminate the project results to all concerned stakeholders in order to collect their feedback regarding the appropriateness of the transition to the subsequent stages of the R&I cycle.

The dissemination objective has been ongoing during all the course of USEPE project**.** USEPE has disseminated its intermediate and final results and shared the challenges ahead in many forums, to name a few:

- World ATM Congress in October 2021, Madrid
- Netware Conference in November 2021, Athens
- POLIS Annual Conference in December 2021, Brussels
- SESAR Innovation Days in December 2021, Online event
- UAM at the Amsterdam Drone Week in March 2022, Amsterdam
- Norway Nordic Edge Expo in April 2022, Stavanger
- AIM2 North Symposium in April 2022, Oslo
- USEPE Open Simulation Day in June 2022, Online event
- ICUAS International Conference in June 2022, Dubrovnik

Further, USEPE project has confirmed its attendance to the following events that will take place after the draft delivery of this report:

- EU Drones' Days in November 2022, Brussels
- POLIS Annual Conference in November 2022, Brussels
- SESAR Innovation Days in December 2022, Budapest

As far as publications are concerned, USEPE has submitted several papers:

- To IARIA Journal in November 2021: "Drones Operations and Communications in an Urban Environment" was awarded as one of the Best Papers during Sensor Devices 2021 Conference by IARIA Board [18].
- To Journal of wind engineering and industrial aerodynamics in February 2022: "Atmospheric Flow Simulation Strategies to Assess Meteorological Conditions for Safe Drone Operations in Urban Environments". The paper was accepted in August 2022 and published in the October 2022 issue of the journal [19].
- To IEEE Conference ICUAS in June 2022:
  - Machine Learning Attempt to Conflict Detection for UAV with System Failure in U-Space: Recurrent Neural Network, RNN [20].
  - A proposal for a common metric for drone traffic density [21].
  - A model for a safer drones' operation in urban environment [22].
  - How to stay well clear in corridors and swarms: Detect-and-avoid ranges for geovectoring concepts [23].

In order to obtain feedback from stakeholders and U-space community to refine the project ConOps (that will be delivered as D3.3, in late December) a Final Workshop was held in Madrid in November 2022.

2.3 Work Performed

This section describes the technical work performed within the scope of USEPE project.

WP3 Separation Concept

In WP3, the Concept of Operations for the separation management was described together with the potential design concept that was later developed in WP4 after their evaluation and selection. System requirements were also derived for the design concept selected. WP3 has provided the basis for WP4 and WP5 and was broken in different tasks:

Task 3.1 (Stakeholders' needs and requirements), aimed at collecting requirements through quantitative and qualitative approaches. The USEPE project appraised a survey delivery to stakeholder and organised a virtual workshop in March 2021 with a wide set of stakeholders and including Advisory Board members where all views, positions and concerns were taken into account. This process led to identify the stakeholders' needs, which were transformed into stakeholders' requirements. Further, the stakeholders proposed the three different scenarios that were later considered through the USEPE project. The stakeholders' needs and stakeholders' requirements were initially included in the ConOps Outline [10].

Task 3.2 (Concept of Operations and design concepts) was devoted to the elaboration of the ConOps. Based on the stakeholders' requirements obtained through Task 3.1, a ConOps Outline was firstly elaborated. For this concept, the potential design concepts were identified and evaluated in order to select the most appropriate to implement in WP4. A new method based on density-based airspace approach together with the addition of the airspace structure based on high-speed corridors and segments described using geovectoring syntax (the D2-C2), was described. In addition, three different scenarios, considering the stakeholders inputs were elaborated, and for each scenario, two different use cases were described (nominal and non-nominal).

Task 3.3 (System requirements) comprised the elicitation of the system requirements. Once the design concept was selected, the system requirements were elicited and traced back to the needs and stakeholders' requirements. These requirements were proposed for the inputs and outputs that the D2-C2 method has to comply with to perform its functions. Finally, when the simulation campaign was finished, the status of those requirements was updated according to the validation results.

Finally, Task 3.4 (Consolidated Concept of Operations) comprised the elaboration of the Consolidated ConOps. Based on simulation and validation results, as well as inputs from presentations in conferences, the ConOps Outline was consolidated in the form of an Initial Concept of Operations [11] which could enable USEPE to go through AO/IR gate. Finally, once the Final Workshop was held in Madrid and more inputs from stakeholders were collected, the USEPE Consolidated Concept of Operations [12] will be elaborated by the end of the project.

WP4 Development of Design Concept

WP4 has been orientated in two main directions: on one side, the design concepts selected in WP3 for U-space separation management were implemented in a simulation tool, including the adaptation of the simulation environments used (e.g., creation of 3D maps, acquisition of drone performance datasets, inclusion of turbulent wind shear data in the simulations, etc.); on the other side, applications of Machine Learning algorithms were investigated in order to improve the separation management. Following this distinction of the work performed, it was divided in two different tasks: T4.1 Design concepts implementation and T4.2 Machine Learning algorithms research.

The BlueSky simulation platform was selected for implementing the design concepts after benchmarking a set of criteria, which included the capability of importing 3D maps, the capability of defining separation metrics, the importation of wind conditions or the importation of multiple UAV specifications.

It is well known that turbulent wind can significantly affect aircraft operations at low flight levels, where UAVs will mainly operate in the urban environment. For this purpose, the BlueSky air traffic simulator has to receive and process wind field data generated by the open-source turbulence simulation model PALM[2]. As input data for BlueSky, the horizontal wind vector components *u* and *v* are simulated with a spatial resolution of 2m for the areas of interest of the USEPE exercise scenarios. The wind data is used in the BlueSky simulator not only to modify drones flight path but also to influence the actions of the segmentation service rules defined in the scope of the D2-C2 separation method. The command WIND allows to input wind velocities in the simulator. It defines a wind vector (or a profile) at a specified position (and optionally at altitude).

The urban environment employed in the simulation is modelled in order to represent in the simulation the characteristics of the city selected, in USEPE case, Hannover city but it could be any other providing that the layout of streets, open spaces, rivers or other geographical features and building heights are

[2] Overview of the PALM model system 6.0, Geosci. Model Dev., 13, 1335–1372, https://doi.org/10.5194/gmd-13-1335-2020.

available. The airspace above the cities to accommodate D2-C2 has been modelled through the use of a graph. This definition is particularly interesting for USEPE because BlueSky relies on the concept of waypoints for providing commands to the aircrafts in the simulation.

A path planning module was implemented to calculate the optimal trajectories from origin to destination using the graph information and transforming those trajectories into BlueSky commands.

With that, the simulation framework has been able to represent drone operations in an urban environment. On top of that, the separation methods described in the ConOps were implemented in the simulator, which included the following modules:

- Corridors: The corridors have been implemented to be included in the airspace available for the drones in the simulation considering the horizontal limits of the city and the VLL upper vertical limit. This implies to model the corridors as a set of waypoints forming the layout of the corridor included in the graph of the city created.
- Dynamic airspace segmentation service: The segments are modelled as rectangular cuboids, where each rectangular cuboid encapsulates an airspace volume of identical features (e.g., class, speed max, capacity or geovectoring rules). The segments are dynamically updated based on environment information such as wind field data, the number or frequency of conflicts in a segment, occupancy of the segments or the need of an emergency drone flight. Those updates can change the mentioned features of the segments affected or modify the shape of the segments by splitting or merging them.
- Strategic deconfliction: The system computes how each new user populates the segments based on their flight plan (i.e., expected positions given the expected velocities during its flight). In accordance with the principle of 'First Planned - First Served', if a new flight plan results in an overpopulated segment, the requested operation will be rerouted or rescheduled.
- Performance based conflict detection: The conflict detection method based on the Aircraft Safety Bounds defined in the ConOps has been implemented employing a set of look-up tables to determine if the potential conflict poses a threat for the actual ownship-intruder combination given the performance parameters of both.

The BlueSky simulator core and the components developed (described in depth in D4.1) interact between each other to accomplish the objectives of the simulation experiments performed in WP5 for validating the concepts proposed.

WP4 has investigated in parallel the applications of ML algorithms aiming at contributing to the safe separation or drones while the D2-C2 method is in place. An extensive literature review identified a wide variety of ML algorithms (e.g., fuzzy kNN or neural networks) to be used as quality metrics, such as the pairwise separation score. The use of unsupervised ML algorithms was considered suitable for the task due to its flexibility, efficiency, intuitiveness and seamlessly integration.

The objective of the ML in this project has been to detect potential conflicts between aircraft and to reduce the likelihood of collisions in U-space. The primary data requirements for ML to recognize unsafe behaviour from safe behaviour has been identified.

This new method is based on flight-related information together with pairwise analysis. The separation information is identified by unsupervised ML algorithms, namely fuzzy kNN and aggregated kNN. This new method has been named USEPE_ML (USEPE Machine Learning algorithm). A plugin in the BlueSky

ATM simulator has been developed in order to analyse the performance of the proposed ML methods (USEPE_ML plugin).

An application of ML to path planning was performed, in which the flight plan separation quality was measured in strategic phase, and then, necessary updates were done for better separation. In this case, 3 flight plans were issued in a zone divided into five segments, and the drones go through different segments to complete the flight. The paths that were more conflicting were properly identified, allowing to modify the most conflicting paths. The results showed that after the update the number of conflicts was reduced.

In future work, the quantified information can be used to automate path planning and strategic and tactical conflict detection and avoidance.

WP5 Simulation and Validation

In WP5, validation of the D2-C2 method developed within USEPE was performed. This WP was divided into 3 different tasks: Task 5.1 Validation Plan, Task 5.2 Simulations Execution and Task 5.3 Analysis of Results. Firstly, a Validation Plan was created in which validation exercises and their scenarios were defined.

The three validation exercises of USEPE focused on delivery drones, an emergency drone that needs to be prioritized over all other drones, and surveillance drones. The third exercise additionally included the interference with manned aviation, in this case a helicopter.

For each of the three exercises, validation scenarios were created for both reference and solution cases. In the reference scenarios, separation was performed by legacy methods, i.e., D2-C2 was not applied. In the solution scenarios, which used the same traffic as the reference scenarios, separation was ensured by applying D2-C2. Each exercise created their own traffic scenarios; the first exercise focusing on delivery drones, the second including one drone that had to be prioritized in conflicts with other drones, and the third exercise focusing on surveillance drones that got in conflict with drones traversing the surveillance patterns. The last exercise included manned helicopters having conflicts with drones.

For the simulations of the different exercises, the Open-source platform BlueSky, developed by TU Delft, was used. This platform allows the fast-time simulation of traffic scenarios and supports the simulation of both rotary and fixed wing drones with their particularities. Commercial aviation can be simulated on it as well. D2-C2 was implemented on this platform, and all three exercises used this implementation.

Finally, the results of all three exercises were brought together in one validation report document. Analysis of the results showed the benefits of D2-C2 when compared to legacy methods, i.e., when solution scenarios were compared to reference scenarios. This was documented in the validation report as well and will be summarised in the following sections.

2.4 Key Project Results

The USEPE project's key results will be presented in the following subsections. The main activities carried out during the USEPE project are extended and further detailed below.

2.4.1 Stakeholders' needs and requirements

The stakeholders are any person or organisation interested in and affected by the concept and separation method developed and validated in USEPE. In USEPE scope, stakeholders are not only the people and organisations that have been contacted through the USEPE survey or participated in the first USEPE workshop, but also those people, organisations or both current and past projects whose results are of interest for USEPE but are out of reach of the USEPE partners.

At first, USEPE identified several stakeholders such as citizens, local authorities, aviation authorities, air mobility service providers, air navigation service providers, emergency response organizations and researchers. USEPE project contacted those stakeholders and their needs were elicited with the principal outcome of understanding their specific problem. To this end, the stakeholders' needs (19 in total) were derived from the USEPE survey and first validation workshop and later, they were transformed into 27 stakeholders' requirements. Those stakeholders' requirements keep traceability back with the stakeholders' needs and with future system requirements. For more information, refer to D3.2 [11].

Figure 2. USEPE path from stakeholders' needs to stakeholders' requirements

The stakeholders played an important role in USEPE project. Analysis of both outcomes of the survey and the workshop led to elaborate the USEPE ConOps Outline [10]. An important step of this project was to conduct an in-depth analysis of existing separation methods that were developed by several organizations and other research projects. Thirteen methods were identified and analysed in depth. The shortlist ended up with a set of four separation methods which were considered the most relevant. However, to be able to select one of these methods in a scientific and replicable manner, the stakeholders' needs were considered to elaborate a set of criteria to allow the use of a mathematical decision-making technique Analytic Hierarchy Process (AHP). However, it was not possible to conduct a clear discrimination of the methods to single one the most relevant, as none could fulfil fifty percent of the stakeholders' requirements. Therefore, a new separation method was elaborated.

2.4.2 Dynamic Density Corridor Concept

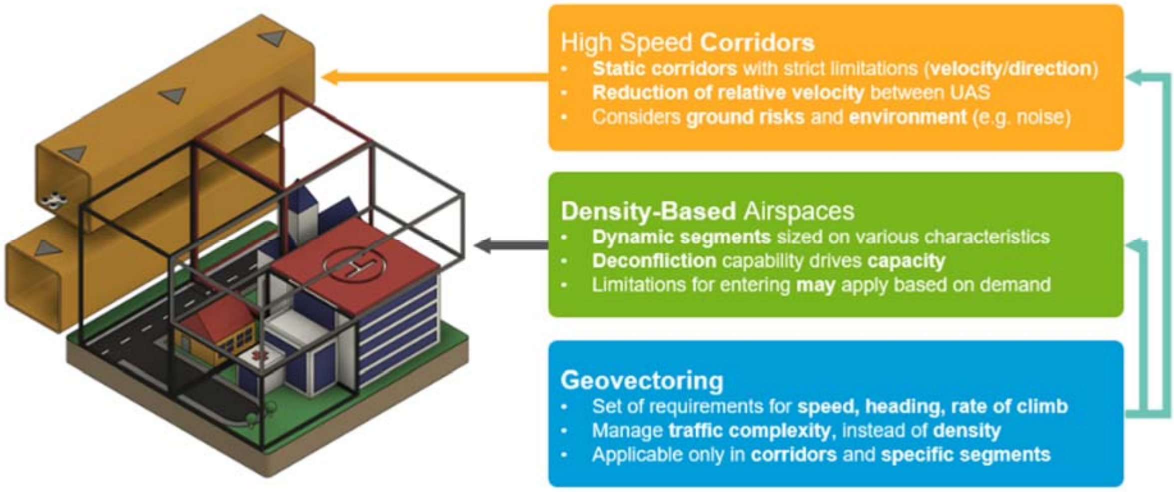
The USEPE Initial ConOps [11] describes the main USEPE outcome, a new separation method, the D2-C2, to provide strategic and tactical conflict resolution in VLL for UAS flying in urban and suburban environments in Zu and Za airspace volumes. This method combines the advantages provided by the following methods: density-based airspace management, high-speed corridors and geovectoring syntax.

In the dynamic segments, in order to allow a rapid and flexible reconfiguration, the airspace is segmented into cells of similar requirements based on airspace usage and each airspace user is modelled by a safety volume defining its relevant performance parameters.

In corridors, drones travel along them in one direction only. Each corridor is like a one-way street, where drones fly in roughly the same direction with similar speed and suitable safety distance and time between them.

Further, geovectoring syntaxis has been applied. The method uses geovectors to limit vehicles mobility in corridors and segments. These geovectors are defined by three components: ground speed, heading angle and vertical speed.

Figure 3. D2-C2 separation method overview



These three methods complement each other to address the potential scenarios and operational needs that typically occur in urban and suburban environments. D2-C2 has been defined to meet stakeholder needs in those environments.

USSPs will benefit from the use of the previously mentioned methods/items to define a tailored airspace structure for every city (taking into consideration particular city characteristics) and accommodate urban drone operations as needed.

The proposed separation method was validated through fast-time simulations. In order to perform reliable simulations providing enough confidence on the results obtained, a set of requirements for the simulator developments of this separation method has been defined.

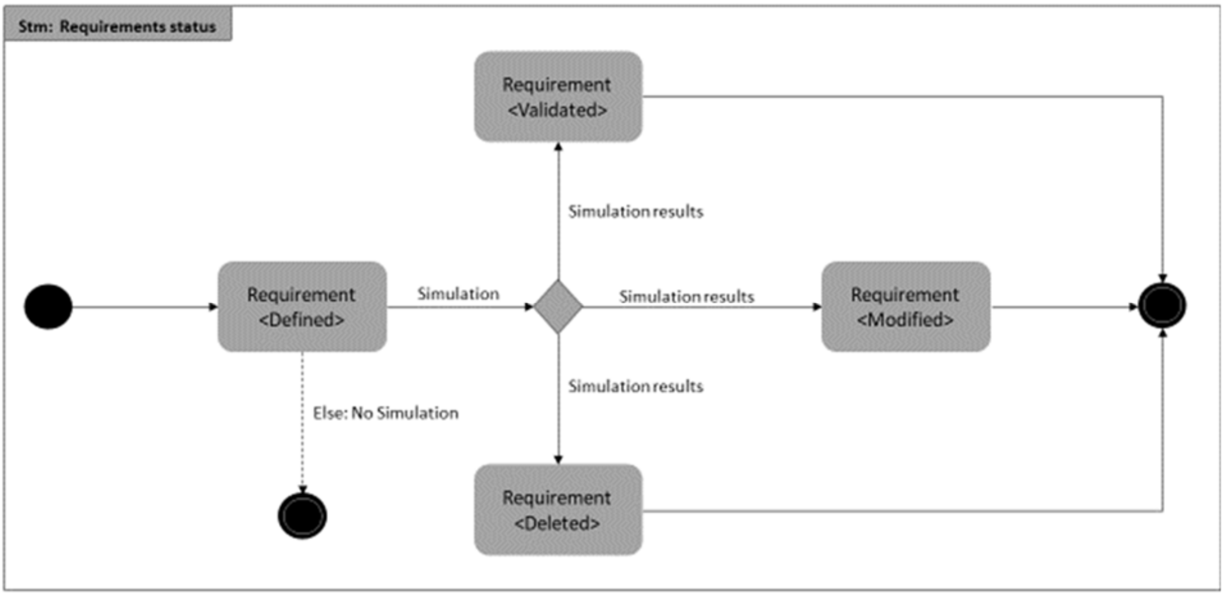
2.4.3 System requirements

Once the D2-C2 separation method was initially defined in D3.1 [10], system requirements were elicited and traced back to the stakeholders' requirements.

The main purpose of deriving requirements in USEPE was to set the basis for the project concept design that were used for the USEPE simulations. System requirements were the foundation of any engineering effort and were statements that identified a product or process operational, functional or design characteristic, which was the inherent meaning of the purpose for deriving requirements in USEPE. A list with 63 requirements was derived.

System requirements were updated in D3.2 [11] once the validation results and the inputs from the final workshop were available. A summary with all system requirements is shown in Appendix B. The process for updating requirements status is showed in Figure 4.

Figure 4. Requirements status update



After the simulations were run, the requirements were changed with respect their status depending on the results:

- Those system requirements that have not been simulated during the validation campaign have maintained their status as <defined>.
- When a requirement has been fulfilled during the validation campaign its status has been updated to <validated>.
- If validation results make it necessary to modify the requirement description or rationale, then the status was updated to <modified>.
- Finally, if a requirement was considered not to be applicable anymore, the status was updated to <deleted>.

Once this analysis was done, 41 requirements were validated. Some of the system requirements already stated in D3.1 have required modifications in order to be aligned with the simulation campaign. Due to this update, just two requirements have changed its status to deleted: one of them was considered as redundant (REQ-USEPE-D31-0110) and other one (REQ-USEPE-D31-0590) was not expected to be useful for future USEPE purposes.

2.4.4 Validation results

The D5.1, USEPE Validation Plan [15] defined 18 objectives related to the Safety, Capacity and Operational Efficiency KPA's with corresponding success criteria. The success criteria were measured employing a set of Key Performance Indicators, including the number of conflicts, number of Loss of

Separations, average distance flown, on-time performance, total number of flights performed, average flight time, ratio of conflicts per drone flight and ratio of Loss of Separation per drone flight.

The simulation engine limitations and the assumptions required to replicate the D2-C2 in a virtual environment were described in D5.2, USEPE Exploratory Research Validation Report [16]. Those limitations included the lack of provision of tactical (real time) awareness of the buildings, the lack of simulation of the avoidance manoeuvres and the neglection of the human factors such as time to react.

To validate the proposed solution, three exercises were carried out as fast-time simulations. All exercises were tested with 3 different levels of drone traffic densities: low (0.0964 simultaneous drone flights per km^2), medium (0.964 simultaneous drone flights per km^2) and high (9.64 simultaneous drone flights per km^2). This density figures have been obtained as the result of an internal study published as a project paper [21].

The exercises covered **last mile delivery, emergency situations and urban surveillance**. All of them were located in the city of Hannover with different atmospheric conditions. Within each exercise, the results from the application of D2-C2 were compared to the performance of a reference scenario, in which drones were allowed to fly with no restrictions in the urban airspace considered.

- **Last mile delivery:** This exercise considered delivery flights departing from three origin points, with a frequency of 5 minutes, and arriving to only one destination point situated at the city centre. It studied the suitability of the D2-C2 method to distribute the traffic to avoid conflicts in the delivery operations while maintaining certain operational efficiency metrics (e.g., delay). The results showed a good scalability of the method with traffic density, obtaining the highest conflict reductions for the high traffic density case with only a 5% reduction in simultaneous flights managed. Regarding delivery operations, 90% of the flights arrived at their destination with delays lower than 10 minutes with respect to the reference case.

- **Emergency situations:** This exercise considered an emergency flight for blood transfer between two hospitals taking place while a riot prompts the police to deploy surveillance drones in the city centre. It studied the suitability of the D2-C2 method to prioritise certain flights while maintaining certain operational efficiency levels. The results showed that the method adapts the airspace in the event of an emergency drone flight, effectively prioritising it so that the drone avoids any conflict. A reduction of conflict metrics was observed for the all the drones under study accompanied with a considerable reduction of the number of drones simultaneously flying in the area.

- **Urban surveillance:** This exercise studied drones performing surveillance activities, together with the background drone traffic, but also with a manned aircraft (a helicopter belonging to city security forces) passing through the area. In this case, the operations were performed in Zu and Za airspaces, given the proximity of Hannover Airport (HAJ). It studied the suitability of the D2-C2 method to separate surveillance drones from each other and from manned aviation while successfully performing their surveillance operations. The results showed an improvement in safety metrics as well. The method reached its capacity limit for high traffic density, showing a sharp decrease in completed flights, which was expected due to the restrictions in the Za airspace. The results showed the capability of the method to manage both manned and unmanned operations in the same area, while ensuring the completion of surveillance operations.

Table 3 presents the USEPE validation objectives and the results of each exercise that justify the achievement of the objective.

Table 3. Summary of validation results

Validation objective	Objective description	Results from each exercise	Overall success
OBJ-USEPE-001	To assess that D2-C2 separation method can be applied between at least two drones operating simultaneously.	EXE-1: Success, target achieved for medium and high densities. Improvement from reference in low density. EXE-2: Success, method works fine with all densities. EXE-3: Success, method works fine with all densities.	**Yes**
OBJ-USEPE-002	To assess that D2-C2 separation method can be applied regardless of the moment of the day.	Covered considering ASS-USEPE-14, different traffic densities and wind simulations representative for a full set of key moments of the day.	**Yes**
OBJ-USEPE-003	To assess that the D2-C2 separation method can be applied to rotary wing drones.	EXE-1: Success, target achieved for medium and high densities. Improvement from reference in low density. EXE-2: Success, method works fine with all densities EXE-3: Success, fewer LOS events with solution scenario.	**Yes**
OBJ-USEPE-004	To assess that the D2-C2 separation method can be applied in VLOS and BVLOS (RLOS).	EXE-3: Success, no loss of separation related to the VLOS operated drone. The VLOS operated drone flew its preferred trajectory on time. Not tested in EXE-1, EXE-2.	**Yes**
OBJ-USEPE-005	To assess that the D2-C2 separation method can be applied in urban and suburban environments.	EXE-1: Success. EXE-2: Success. EXE-3: Success, fewer LOS events with solution scenario.	**Yes**
OBJ-USEPE-006	To assess that the D2-C2 separation method can prioritize flights.	Not tested in EXE-1. EXE-2: Success, emergency drones are prioritised increasing the safety. Not tested in EXE-3.	**Yes**
OBJ-USEPE-007	To assess that the D2-C2 separation method can separate drones from manned aircraft.	EXE-3: Success, fewer LOS events between manned and unmanned aircraft with solution scenario. Average distance flown only increased by 12%. Not tested in EXE-1, EXE-2.	**Yes**
OBJ-USEPE-008	To assess that the D2-C2 separation method can	EXE-1: Success. EXE-2: Success.	**Yes**

	decrease avoidance manoeuvres and conflict domino effects (aggregated/city level).	EXE-3: Success, fewer LOS events with solution scenario.	
OBJ-USEPE-009	To assess that the D2-C2 separation method can deal with contingencies to accommodate the expected demand.	EXE-1: Success. EXE-2: Failure, fewer completed flights in solution scenario (on-time performance not tested in EXE-2). EXE-3: Failure, fewer completed flights in solution scenario (on-time performance not tested in EXE-3).	**Partial** Traffic in exercises 2 and 3 was expected to be lower, as they validate exceptional situations
OBJ-USEPE-010	To assess that the D2-C2 separation method can be applied in a region of the airspace located in the vicinity of buildings (urban canyon).	EXE-1: Success, target achieved for all densities analysed. EXE-2: Success, target achieved for all densities analysed. Not tested in EXE-3.	**Yes**
OBJ-USEPE-011	To assess that the D2-C2 separation method can apply separation in a Zu airspace for different densities of the drones flying over the buildings.	EXE-1: Success, target achieved for higher densities. Improvement from reference in low density. EXE-2: Success, target achieved for all densities analysed. EXE-3: Success, fewer conflicts per drone in Zu airspace with solution scenario.	**Yes**
OBJ-USEPE-012	To assess that the D2-C2 separation method can apply separation in a Za airspace for different densities of drones flying over the buildings.	EXE-3: Success, fewer conflicts per drone in Za airspace with solution scenario. Not tested in EXE-1, EXE-2.	**Yes**
OBJ-USEPE-013	To assess that the D2-C2 separation method can apply separation when a no-fly zone is dynamically created.	Not tested in EXE-1. EXE-2: Success, target achieved for all densities analysed. Not tested in EXE-3.	**Yes**
OBJ-USEPE-014	To assess that the D2-C2 separation method can handle the effects of a major disruption in a corridor (corridor closure) in the separation management.	Not tested in EXE-1. EXE-2: Success, target achieved for all densities analysed. Not tested in EXE-3.	**Yes**

OBJ-USEPE-015	To assess that the D2-C2 separation method can handle the effects of a major disruption in communications between drone(s) and drone operator or between drone operator and ATC/USSP.	EXE-3: Success, fewer LOS events per drone with solution scenario. Not tested in EXE-1, EXE-2.	**Yes**
OBJ-USEPE-016	To assess that the D2-C2 separation method can be applied to last mile delivery, emergency and urban surveillance situations.	EXE-1: Success, traffic reduced in less than a 30% and fewer LOS events with solution scenario. EXE-2: Partial success, traffic reduced by more than 30%, but fewer LOS events with solution scenario. EXE-3: Partial success, traffic reduced by more than 30%, but fewer LOS events with solution scenario.	**Partial** Traffic in exercises 2 and 3 was expected to be lower, as they validate exceptional situations
OBJ-USEPE-017	To assess that the D2-C2 separation method can increase airspace capacity.	EXE-1: Failure, longer flight time and fewer completed flights with solution scenario. EXE-2: Failure, longer flight time with solution scenario. EXE-3: Failure, longer flight time and fewer completed flights with solution scenario.	**No** The result is expected, as the "safety first" principle often trades efficiency of traffic for safety bounds
OBJ-USEPE-018	To assess that the D2-C2 separation method can allow a rapid, flexible and efficient reconfiguration of the airspace according to the traffic density.	EXE-1: Success, target achieved for all densities analysed. EXE-2: Success, target achieved for all densities analysed. EXE-3: Success, target achieved for medium and high densities.	**Yes**

The results of the three exercises were correlated with the KPI's target levels defined in each success criteria. According to that, **17 out of 18 objectives were achieved, so the validation can be defined as successful**. The objective that was not successfully validated is related to the increase in airspace capacity when applying D2-C2. It has not been achieved in any exercise, except when traffic density is low. The result was to some extent expected given the inclusion of restrictions to the flights with the separation method. The slight decrease of airspace capacity and sharp increase of safety metrics overcome the fact of not achieving this objective.

2.4.5 Machine Learning achievements

The USEPE project was accompanied by Machine Learning (ML) algorithms that will aid the proposed solution to be enhanced when fully applied. ML developments and implementations were explained in D4.2 [14]. The project identified then the primary data requirements for ML to recognize unsafe drone behaviour from safe drone behaviour. The most suitable ML algorithms to be applied to USEPE were identified and verified in D4.2. The focus of those ML algorithms was placed to detect conflictive situations between aircraft and to reduce the likelihood of collisions in U-space. Also, the developed algorithm was flexible enough to be applicable beyond U-space.

One particular ML algorithm that uses the abstract definition of "drone flight" (which is a term used to describe Unmanned Aerial Vehicles (UAVs)) was developed. This was done by learning from flight information in multiple phases, such as strategic and tactical phases. The algorithm was named USEPE_ML (USEPE Machine Learning algorithm). Although USEPE_ML has been applied to unmanned traffic, it could be expanded for mixed traffic, manned and unmanned flights, and make decisions accordingly. USEPE_ML required at least 2 drones, but it does not have an upper limit number of drones. However, increasing the number of drones requires more computational time. Also, USEPE_ML does not require any specific hardware/software, but it is necessary to know all drone positions during computation.

This new algorithm was based on flight-related information together with pairwise analysis. The separation information is identified by unsupervised ML algorithms, namely fuzzy kNN and aggregated kNN, to provide a complementary solution. The main idea behind the Fuzzy kNN algorithm is to assign a probability to pairs. The Aggregated kNN algorithm combines several results from Fuzzy kNN instances. USEPE_ML is implemented in a plugin form for BlueSky ATM simulator.

USEPE_ML approach considered three types of separation scores: Pairwise, General and Local separation scores. The normalized separation scores change between 0 (stands for the worst separation) and 1 (stands for the best separation). Pairwise Separation Score (PSS) is the strength of fuzzy clusters. Fuzzy clustering in USEPE project is a method used to combine the considered drone pairs as objects. General Separation Score (GSS) is an assigned score of a separation quality of a drone. GSS excludes the outliers of the reference drone to detect unusual activities by Aggregated kNN. Local Separation Score (LSS) is a specialized form of GSS. LSS measures the separation limited with nearby drones. The limit is provided as a certain number of drones to respond to any error because of GSS adaptation in extreme setups. Also, LSS provides information about the nearby separation, so LSS identifies the immediate quality or dangers. Lower scores indicate a separation problem(s), so operators may need to take an action such as updating the path plan or applying conflict resolution.

All three scores were designed to serve USEPE concept D2-C2 and verified by KPIs such as number of conflicts. Lastly, all computations are done in three flight phases: strategic, tactical and summary phases.

2.5 Technical Deliverables

The following Table 4 presents a brief description of all technical deliverables that were included in USEPE's Grant Agreement. Please note that deliverables from the non-technical work packages WP1, WP2 and WP6 are not included.

Table 4. Project Deliverables

Reference	Title	Delivery Date[3]	Dissemination Level[4]
Description			
D3.1	USEPE Concept of Operations Outline	30/06/2021	Public
Based on the stakeholders' requirements, a Concept of Operations Outline was elaborated. For this concept, the potential design concepts were identified and evaluated in order to select the most appropriate to be implemented. Once identified, the new separation method (the Dynamic Density Corridor Concept) was described. In addition, three different scenarios (last mile delivery, emergency situation and urban surveillance), considering the stakeholders inputs were elaborated. Further, system requirements derived from the stakeholders' needs and requirements were also elicited, showing the traceability between them.			
D3.2	USEPE Initial Concept of Operations	31/10/2022	Public
D3.2 represented an update of D3.1. Based on simulation and validation results, the Concept of Operations Outline was consolidated in the form of an Initial Concept of Operations. The D2-C2 method, as well as the three scenarios were refined with those results and with the inputs received during the course of the project. This could enable USEPE to go through AO/IR gate.			
D3.3	USEPE Consolidated Concept of Operations	23/12/2022	Public
D3.3 will represent an update of D3.2. Based on inputs from presentations in conferences, the first version of the Initial Concept of Operations will be improved with the information obtained and gathered, which could enable USEPE to go through AO/IR gate.			
D4.1	Report on design concepts implementation	31/08/2022	Public
In this document, the process for defining and developing the simulator for testing the separation method, the D2-C2, was presented. The document included the description of the problem under study and the requirements of the simulation tool to be used in the context of the USEPE project, the description of the traffic simulation platform (BlueSky), wind simulator (PALM) and required developments to simulate drone traffic within a city and the implementation of additional modules to represent USEPE separation method (D2-C2). The method presented effectively simulates urban drone traffic in any city provided the specific inputs (e.g., buildings 3D model), making it a useful tool for research in the U-space field.			
D4.2	Report on Machine Learning Algorithms	31/10/2022	Public
D4.2 contributed to the development of the safety system for UAVs. D4.2 presented the Machine Learning method developed in the USEPE project. In this document a complete analysis of the developed ML methods was performed and the results of the verifications are included. Further, the performance of the proposed ML methods was analysed using BlueSky ATM simulator and performance evaluations of the algorithms are presented. The report was the final version of a comprehensive document with the tasks related to the exploration and implementation of ML for ensuring a safe drone operation. The document was due March 2022 but USEPE and SJU reached an agreement to deliver the document in two phases, being the October 2022 version the full and only version.			
D5.1	Validation Plan	31/10/2021	Public
D5.1 provided the Validation Plan for the exercises that validated the separation method proposed after the analysis and selection in USEPE D3.1 as part of V1 maturity level activities. D5.1 followed E-OCVM guidelines.			

[3] Delivery data of latest edition

[4] Public or Confidential

Three different validation exercises were selected: last mile delivery, emergency situation and urban surveillance, sufficient to successfully achieve the maturity level for the SESAR SOL-USEPE under its scope. For all three exercises, this document specified the validation technique, the platform used, the information related to the expected data, the data collection method and the data analysis.			
D5.2	USEPE Exploratory Research Validation Report	16/11/2022	Public
D5.2 presented the validation results of the USEPE ConOps, focused on the testing of the capabilities of the D2-C2. The results presented follow the plan depicted in USEPE deliverable D5.1 Validation Plan. This document included the context of the validation activities, clearly stating the scope of the validation activities and the limitations imposed by the simulation engine developed; the validation approach, which described the inputs and outputs of the simulations and the way the outputs were treated; the validation exercises performed and the results obtained and the conclusions extracted from the validation activities aim at supporting the refinement of the ConOps and proposals for future research activities were derived.			

3 Summary of Communications and Dissemination activities

3.1 Summary of communications and dissemination activities

The following communication and dissemination activities at conferences and similar events have been carried out during the USEPE project:

Table 5. USEPE communication and dissemination activities

Activity	Event Date	Type of Communication	Partner Involved	Type of Document
Polis ACCESS Working Group meeting. First encounters with Urban Air Mobility	22 March 2021	Event	POLIS	Presentation
First USEPE workshop to gather users' needs	23 March 2021	Event	CONSORTIUM	Presentation
SESAR U-space workshop	20 May 2021	Event	ISDEFE	Presentation
European University of Madrid. Presentation of master's final thesis on Systems Engineering	25 June 2021	Event	ISDEFE	Presentation
USEPE First Newsletter	29 June 2021	Social Media	CONSORTIUM	Newsletter
Bilateral meeting HELICUS-USEPE about the use of AI to enhance drone separation	30 June 2021	Meeting	CONSORTIUM	Presentation
OPTICS2 Project Final Dissemination	27 September 2021	Event	POLIS	Networking
AURORA Stakeholders Workshop	28 September 2021	Event	POLIS	Networking
World ATM Congress Madrid	26 October 2021	Event	ISDEFE	Project Leaflets at ISDEFE Stand
World ATM Congress Madrid	27 October 2021	Event	NOMMON	Presentation
Presented paper at 12th International Conference on Sensor Device Technologies and Applications, SENSORDEVICES 2021 Athens, Greece	14 November 2021	Event	USN	Conference Paper
NetWare-2021 Congress, Athens (Greece) being a panellist, gave presentation on USEPE project and discussed the challenges on concepts of safe separation	18 November 2021	Event	USN	Panel Discussion
USEPE Second Newsletter	23 November 2021	Social Media	CONSORTIUM	Newsletter
Unmanned Nordic Conference 2021	24 November 2021	Event	INDRA	Networking
POLIS Annual Conference 2021	01 December 2021	Conference	POLIS	Presentation
SESAR Innovation Days (virtual)	07 December 2021	Event	CONSORTIUM	Poster and Video, Live Presentation

Activity	Event Date	Type of Communication	Partner Involved	Type of Document
"Journal of wind engineering and industrial aerodynamics": Paper on Atmospheric Flow Simulation Strategies to Assess Meteorological Conditions for Safe Drone Operations in Urban Environments	9 February 2022 Published October 2022	Journal	LUH	Scientific Paper
USEPE Third Newsletter	28 February 2022	Social Media	CONSORTIUM	Newsletter
Universidad Europea of Madrid, Spain *"How Systems Engineering is Being Applied in the USEPE Project"*	22 March 2022	Master Class	USN	Presentation
UAM at the Amsterdam Drones Week (hybrid) *"USEPE integrates the Pan-European Urban Air Mobility Projects & Initiatives Community"*	20-31 March 2022	Conference	POLIS	Presentation and Networking
AIM2NOrth, Oslo *"How Artificial Intelligence could foster safe drone operations in urban areas"*	6 April 2022	Conference	USN	Presentation
Norway Nordic Edge Expo	11 May 2022	Conference	USN, POLIS	Presentation
Urban Air Mobility for All Workshop, Brussels	17 May 2022	Workshop	POLIS	Presentation
ASSURED-UAM Advisory Board Meeting	19 May 2022	Workshop	POLIS	Participation and Networking
CCC#06	19 May 2022	Meeting	ISDEFE	Participation and Networking
USEPE Fourth Newsletter	31 May 2022	Social Media	CONSORTIUM	Newsletter
The KSEE Systems Engineering, Kongsberg: Using Machine learning to improve drone traffic management	15 May 2022	Conference	INDRA, USN	Presentation
USEPE Open Simulation Day Info About Validation Exercises, BlueSky Simulator, ML and weather simulations	16 June 2022	Online Workshop	CONSORTIUM	Video and Presentation
ICUAS '22 Dubrovnik, Croatia *"Machine Learning Attempt to Conflict Detection for UAV with System Failure in U-Space: Recurrent Neural Network, RNN"*	21-24 June 2022	Conference	USN	Paper
ICUAS '22 Dubrovnik, Croatia *"A proposal for a common metric for drone traffic density"*	21-24 June 2022	Conference	INDRA, DLR, USN	Paper
ICUAS '22 Dubrovnik, Croatia *"A model for a safer drone's operation in urban environment"*	21-24 June 2022	Conference	INDRA, DLR, USN, ISDEFE	Paper
ICUAS '22 Dubrovnik, Croatia *"How to stay well clear in corridors and swarms: Detect-and-avoid ranges for geovectoring concepts"*	21-24 June 2022	Conference	DLR	Paper

Activity	Event Date	Type of Communication	Partner Involved	Type of Document
ICUAS '22 Dubrovnik, Croatia USEPE Workshop Presentations and Panel 1. Welcome (ISDEFE) 2. U-space Separation in Europe (USN) 3. Drone traffic densities (INDRA) 4. How to stay well clear (DLR) 5. Turbulent Wind Field BlueSky (LUH) 6. Implementation on a novel concept in BlueSky (NOMMON) 7. Can AI be a good approach to safe drone operations an urban airspace? (USN) 8. UAV path planning in search and rescue missions (USN) 9. The role of local authorities in UAM (POLIS) 10. Panel discussion	21 June 2022	Workshop	CONSORTIUM	Presentations
SESARs E-news Project of the Month	11 July 2022	Social Media	CONSORTIUM	SESAR Webpage, LinkedIn
Sikker Integrasjon av Droner 2022 Topic: Separasjon mellom droner og fly i et integrert luftrom	30 August 2022	Conference	USN, INDRA	Presentation
CCC Langen, CORUS CONOPS seminar	27-28 September 2022	Workshop	USN, ISDEFE, INDRA	Presentation
USEPE Final Workshop in Madrid, Spain	8 November 2022	Workshop	CONSORTIUM	Presentation, Videos and Surveys
EU Drone Days	29-30 November 2022	Conference	USN, ISDEFE	Stand and Presentation
POLIS Annual Conference 2022	1 December 2022	Conference	POLIS, USN	Stand and Presentation
SESAR Innovation Days 2022	5-8 December 2022	Conference	USN	Poster and Presentation

At the beginning of the project, USEPE opted to present the project general aim and the specific project Systems Engineering approach.

With a view to positioning USEPE in relation to other Air Mobility research projects in September 2021, USEPE's partner, POLIS Network, attended two events:

- The final dissemination event of the Observation Platform for Technological & Institutional Consolidation of research in Safety OPTICS2 project. OPTICS2, an EU project, provided a state of the art on the recently or currently conducted aviation research.
- The first stakeholder workshop of the AURORA project. AURORA analysed the societal acceptance of Urban Air Mobility (UAM), based on several criteria (environment, integration with surface mobility, safety and security, and societal challenges).

During Madrid World ATM Congress (WAC), USEPE leaflets were available at ISDEFE stand and USEPE partners attended the WAC met at this stand. Further, NOMMON presented the innovative USEPE ConOps (D2-C2) in the Tower Theatre at WAC in October 2021. The presentation was part of a greater event held together with DACUS, BUBBLES and AMU-LED, all of them SESAR funded projects. The four projects addressed and openly discussed the challenges of Advanced U-space Services and concepts in urban environment during a joint panel discussion.

Throughout November 2021, several communication activities were carried out in USEPE. Being one of the panellists at NetWare 2021 Congress, Athens (Greece), USEPE's partner USN, gave a presentation on USEPE project, explained its objectives and goals, and discussed the challenges on concepts related to safe separation of drones. Further, another project partner, INDRA attended Norway's most important drone conference, Unmanned Nordic Conference 2021, in Stavanger. It was hosted by UAS Norway, the Norwegian drone industry association. INDRA interacted with various vendors and organizations and promoted the USEPE project, its objectives and the new concept of D2-C2 separation method.

USEPE took part and gave a speech at the POLIS Conference in December 2021 in Gothenburg, (Sweden) in a common session with other Urban Air Mobility projects related. In this event, POLIS presented the advancement of separation D2-C2 focused on activities related to air mobility in urban areas, highlighting the challenges and opportunities for citizens and cities that may be arise from the use of drones in such environments.

The entire USEPE team attended the 11th SESAR Innovation Days, held virtually. A teaser video and poster were available during the Exhibition Webinar. In addition, the USEPE team presented the preliminary results at the SIDs and organized a live Q&A session in order to interact with the participants.

USEPE integrates the Pan-European Urban Air Mobility Projects & Initiatives Community during the Amsterdam Drone Week in March 2022. This community aims to facilitate knowledge sharing across UAM projects and initiatives in Europe. Synergies are required to enhance results, multiply impacts and ensure a coordinated approach between the involved projects and initiatives.

In April 2022, USN attended the AIM2North Conference at the Oslo Metropolitan University (Norway) to explain the USEPE project. The talk outlined preliminary results of the USEPE project that aims to explore the use of Machine Learning to ensure the safe separation of drones operating in an urban environment, presenting the ConOps and discussing the Ethics of Using Artificial Intelligence as well in the aviation domains.

During May 2022, POLIS kept some meetings and networking activities to promote the project, as was the Norway Nordic Edge Expo, the Urban Air Mobility for all workshop and the Assured-UAM Advisory Board Meeting. Stakeholder engagement conducted in the project should raise the awareness of citizens and local authorities, thus improving the understanding and integration of UAM in urban mobility.

Part of the dissemination activities was the organisation of the Open Simulation Day, an online gathering for people, companies and stakeholders interested in the U-space mobility and policy in one place. In this event, USEPE partners presented the validation process on last-mile delivery, emergency services and urban surveillance and the most recent achievements of the project.

In June 2022, ICUAS Conference on Unmanned Aircraft Systems took place in Dubrovnik (Croatia), where USEPE presented the potential separation methods to ensure the safety of drone operations in urban environments. A public workshop event report was organised as a part of the USEPE dissemination event. USEPE Consortium were able to present the main objectives and tasks of the projects and to combine the best available methods. All partners were also able to engage in the highly interactive technical discussions with the visitors during the workshop. It was a valuable experience for the Consortium, to exchange the knowledge and opinions on the U-space for the future Air Mobility. During ICUAS, all partners submitted some papers as indicated in Section 2.2, a special session was organised at the conference with moderators from the Consortium. A stand showcasing USEPE was also organised during the event. All members had an active role in presenting USEPE concepts, demonstration of results and gathering comments from the conference attendees.

On the 8th of November, the USEPE Project team attended the Final ConOps Workshop “U-space for future Urban Air Mobility: concepts and challenges” in Madrid (Spain). Before the event, the ConOps was shared with the stakeholders' representing authorities, researchers, regulators and industry from all across Europe. During the workshop, the project results were explained and discussed with the participants during a round table discussion and later on in small groups. Thanks to the external participants, the team was able to find the gaps in the Initial ConOps and all the comments and recommendations will be included in the USEPE Consolidated ConOps [12].

At the end of November and the beginning of December, USN and ISDEFE will travel to Brussels (Belgium) to represent USEPE at the EU Drone Days. A poster was arranged with the organisation. In parallel, POLIS will organise a session on UAM with several EU-funded projects on the topic (AURORA, AiRMOUR, UAM School for cities) to promote USEPE further among cities and regions. After that, USN will travel to the SESAR Innovation Days 2022 in Budapest (Hungary) to represent USEPE with a poster.

Additionally, there are other communication channels for continuous dissemination including the website [24] and LinkedIn page. On the website, the introduction of the project, the participation of the Consortium members, updates about the project and released deliverables are served to the public and experts. The subscription feature notifies interested parties of all updates. The project used LinkedIn to spread the good news. LinkedIn page was used to inform about newsletters publication, to announce the simulation campaign and to share some simulation highlights.

3.2 Project High Level Messages

The three high-level messages defined in this section are interconnected: stakeholders are concerned about safe separation. Other Key Performance Areas will also be addressed as part of the project, but safety performance, more precisely, safe separation from other drones and manned aircraft or fixed objects in densely populated areas, is paramount to USEPE as it is paramount to the stakeholders.

Key Message #1: Drones operating in a U-space context can be separated in a safe manner

The goal of USEPE is to propose, develop and evaluate a Concept of Operations and a set of enabling technologies aimed at ensuring the safe separation of drones (from each other and from manned aviation) in the U-space environment, with particular focus on densely populated areas**.** For this purpose, the project has defined the D2-C2 separation method and three different scenarios: last mile delivery, urban surveillance and emergency situation.

As a summary, D2-C2 method distributes the traffic more homogeneously within the airspace available than the simple path planning which selected the shortest path between origin to destination in terms of distance or travel time. The dynamic segmentation and corridor definitions are capable of managing the traffic load and characteristics in the different areas of a city, regardless the time of day, weather conditions or other occurring situations. Without considering exceptional situations such as emergency flights, the method provided an increase in simultaneous flights managed in low and medium density and a reduction of only a 5% when analysing high density in the last mile delivery exercise. It was observed in all exercises that the drones make a better usage of the airspace at higher altitudes.

The results achieved indicates that the USEPE Solution maintains safety levels at higher traffic densities than the simple path planning based on the shortest distance.

Key Message #2: Machine learning can be beneficial to automate the U-space separation management system

USEPE explores how innovative approaches such as AI and ML could open a new range of possibilities for drones' operations in a challenging urban setting. To this end, USEPE has worked to define a novel ML algorithm for safe separation. The defined framework uses a set of features that are extracted from the abstract flight definitions. The unsupervised ML algorithm helps D2-C2 implementations, such as route planning and dynamic segmentation, to address better the dynamic nature of U-Space. In the case study defined in D4.2 [14], improving path planning was presented. In the strategic phase, the separation qualities of the drones and drone pairs were analysed by the USEPE_ML algorithm, so the separation quality was increased by the updated path. The result was verified by reduced simulation time and the number of conflicts. Moreover, the applications are endless such as separation scores can be used to select the best manoeuvre to solve conflicts efficiently, improving safety and separation in the tactical phase.

Key Message #3: Stakeholder needs are necessary to ensure the safe separation of drones in U-space

There are several approaches to address the issues of safe space separation. However, there are still some challenging issues to address. Therefore, USEPE aims to explore how the use of techniques from AI such as ML could address better these issues. The approach is based on a systematic system engineering process and takes into account the stakeholder's needs.

An important activity of the project was to ensure a smooth and efficient communication not only within the consortium but also towards the scientific, public and private communities. In addition, being aware of the needs or requirements of various stakeholders, ranging from legal to technical fields, was also important for the success of USEPE. Participative design, more specifically in the ConOps was an essential part of the project. The three scenarios considered through the whole project were also defined based on stakeholders' needs, thus ensuring the consideration of the growing concerns on the use of drones and potential applications in an urban setting.

4 Links to SESAR Programme

4.1 Contribution to the ATM Master Plan

One of the main targets highlighted in the European ATM Master Plan [38] is the integration of all aerial vehicles, manned and unmanned. The realisation of the vision also depends on the integration of the wide variety of new aerial vehicles accessing the airspace alongside conventional manned aircraft. To this end, U-space is designed to fast-track the development and deployment of a fully automated drone management system, in particular for but not limited to VLL airspace.

U-space is an enabling framework including a set of new services along with specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones. It is developed in an agile way using short life cycles in which technologies are deployed as they become mature. This is done in four phases (U1, U2, U3 and U4), which serve as the basis for the gradual deployment of services.

USEPE aims to mainly contribute to the strategic and tactical conflict resolution services, framed into phases U2 (initial services) and U3 (advanced services) respectively. USEPE project seeks to increase the range of operations at VLL and to unlock new and enhanced applications and mission types in high-density and high complexity areas, i.e., urban and suburban environments.

Table 6. Project Maturity

Code	Service Name	Environment	Project contribution	Maturity at project start	Maturity at project end
U2S-03	Strategic conflict resolution	<urban> <suburban> <deliveries> <surveillance>	USEPE provides a new separation method for strategic deconfliction. The airspace is initially divided into segments and corridors with a maximum capacity associated, calculated in function of the aircraft safety volumes that can fit within it without intersection. Based on the flight plan, new users are included into those segments. In order to allow a new flight plan to enter in a segment or corridor, the strategic conflict resolution service evaluates the proposed flights and approves them if no issues are detected.	V0/TRL-0	V1/TRL-2
U3S-02	Tactical conflict resolution	<urban> <suburban>	USEPE contributes with its new separation method to the tactical deconfliction layer.	V0/TRL-0	V1/TRL-2

		<deliveries> <surveillance>	When a conflict is not solved in a strategic deconfliction phase, due to some unexpected events or disagreements between the expected flight plan and the actual path, it will be tackled by the tactical layer. Tactical conflict resolution service is performed by a U-space service provider, with also monitors traffic. The performance-based conflict detection method provides the optimal resolution manoeuvre to be executed in order to resolve the conflict. The operator of the drone receives the command and is responsible of performing the suggested manoeuvre in both segments and corridors.		

4.2 Maturity Assessment

USEPE (SESAR SOL-USEPE) focuses on the assessment of different existing separation methods for drones and the selection of the most appropriate for its application on densely populated urban and suburban environments in a U-space airspace. The separation method (D2-C2) provided by USEPE places the USSP at the centre of separation management through the provision of strategic and tactical conflict resolution. Although the main focus are the strategic and tactical de-confliction services, any solution, such as the D2-C2 method considered in USEPE, shall be kept as compatible with the rest of U-space services and ATC procedures under CTR environments. To this end, a U-space service V1 Maturity Assessment for each of these two services is provided in the following tables in order to assess the achievement of V1/TRL-2 for the concept overall.

Table 7. Strategic conflict resolution V1 U-space service Maturity Assessment

Criteria ID	Criteria	Satisfaction	Rationale - Link to deliverables - Comments
OPS.V1.1	Is the U-space service definition (after consolidating the project results) aligned with the applicable version of CORUS Concept?	Achieved	Strategic conflict resolution service as defined in USEPE is aligned with the CORUS Concept. With the new separation method proposed by USEPE (the D2-C2), the urban layout and airspace structure (corridors and dynamic segments) are considered when planning the drone operations and considered within the airspace capacity and separation during the strategical phase, thus improving the provision of this service. The D2-C2 method has been detailed in D3.2 USEPE Initial ConOps.
OPS.V1.2	Have potential (sub)operating environments been identified where the U-space service could be deployed?	Achieved	The operational environment foreseen for the strategic conflict resolution service, in the context of USEPE, are the air and ground environments that comprise high densely populated areas, i.e., urban environments, or suburban environments such as industrial areas, roads or highways for entering/exiting a city. The operational environment is detailed D3.2 USEPE Initial ConOps.
OPS.V1.3	Have all stakeholders been identified, their needs and expectations for the U-space service discussed and documented?	Achieved	During the stakeholders' needs elicitation by means of an on-line questionnaire and during the first USEPE Validation Workshop, that took place on the 23rd of March 2021, participating stakeholders shared their concerns and needs that USEPE intends to take into account. When the separation method was selected, these stakeholders' needs were considered and directly influence the strategic conflict resolution service. Those needs are detailed in D3.2.
SYS.V1.1	Does the U-space service proposed architecture aligned to the U-space architecture principles?	Achieved	The architecture follows the U-space architecture principles. These principles are reflected throughout D3.2 (e.g., service-oriented, safety-focused, based on evolutionary development, etc.).
PER.V1.1	Is there a documented description (and if available qualitative evidence) of the potential impacts of the U-space service on SESAR Key Performance Areas (KPAs)?	Achieved	The validation of the USEPE Concept of Operations defines a set of success criteria, which are linked to Key Performance Indicators related with three SESAR KPA's: safety, capacity and operational efficiency. The documented description is reflected in D5.1 (USEPE VALP) and D5.2 (USEPE ER Validation Report).

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PER.V1.2	Has a V1 Human Performance assessment been performed and documented?	Not Applicable	Out of USEPE scope. The concepts for strategic conflict resolution that the USEPE project aims to test are new and need a first theoretical validation phase before scaling up to human-in-the-loop simulations or real demonstrations.
PER.V1.3	Has a V1 Safety Performance assessment been performed and documented?	Not Achieved	No Safety Assessment has been developed.
PER.V1.4	Has the V1 security assessment been carried out?	Not Achieved	No Security Assessment has been developed.
PER.V1.5	Has been a V1 environmental assessment been performed and documented?	Partially Achieved	No systematic environmental assessment was performed, but the corridor allocation criteria proposed in USEPE is expected to ensure environmental protection. Further, corridors can be beneficial to reduce noise and visual pollution in certain areas and concentrate it in those areas where the impact for citizens can be lower.
PER.V1.6	Is there any qualitative estimation or orders of magnitude of deployment costs of the U-space service?	Not Achieved	No CBA has been developed.
S&R.V1.1	Have applicable standards been identified?	Achieved	Current operational policies and constrains are identified in D3.2 (Commission Implementing Regulation (EU) 2019/947, Commission Implementing Regulation (EU) 2019/945). Also, the Commission Implementing Regulation (EU) 2021/664 is considered, where the minimum U-space mandatory and optional services are identified.
S&R.V1.2	Have needs for update/create standards been identified?	Achieved	With the existing regulations, drones cannot fly above a certain altitude either above the ground or above the highest obstacle. Up to now, they do not allow the simultaneous flight of several drones in a small area, which may be necessary in some situations. Considering USEPE's proposal, it can be seen that the current regulation falls short, so it will be necessary to adapt separation aspects to allow the development of the proposed operations and business opportunities.

TRA.V1.1	Are there recommendations proposed to be addressed during V2 related activities?	Achieved	Yes, in D5.2 topics for future research are identified. For the strategic conflict resolution service, an exploration of the implications of the dynamic update segmentation parameters in the KPAs analysed and the consideration of case studies would provide useful insight on the mechanisms that emerge with the segments update rules.
VAL.V1.1	Are the relevant R&D needs identified and documented?	Achieved	Yes, key R&D needs are described in D5.1.
VAL.V1.1	Has the project performed appropriate validation activities at V1 level to support the definition of the U-space service? E.g., fast time simulations, expert groups	Achieved	Yes, to validate the USEPE solution, three exercises (last mile delivery, emergency situations and urban surveillance) were carried out as fast-time simulations. Results are presented in D5.2.
PRG.V1.1	Have dependencies with other U-space services been identified and documented?	Achieved	Yes, for D2-C2 separation method, which involves mainly the strategic and tactical conflict resolution services, some supporting services and stakeholders are required. The interfaces to other U-space services are outlined in D3.2. (e.g., geo-awareness service is necessary for the strategic de-confliction to avoid known issues and restricted airspace. Further, the operation plan processing is needed to check the availability of segments and corridors).

Table 8. Tactical conflict resolution V1 U-space service Maturity Assessment

Criteria ID	Criteria	Satisfaction	Rationale - Link to deliverables - Comments
OPS.V1.1	Is the U-space service definition (after consolidating the project results) aligned with the applicable version of CORUS Concept?	Achieved	Tactical conflict resolution service as defined in USEPE is aligned with the CORUS Concept. In the new separation method (the D2-C2) for allowing tactical conflict resolution, a performance-based conflict detection method has been implemented, based on the Aircraft Safety Bound concept. This method improves traditional conflict detection methods by considering the performance of the drones in terms of avoidance manoeuvres. This method has been detailed in D3.2 USEPE Initial ConOps.

OPS.V1.2	Have potential (sub)operating environments been identified where the U-space service could be deployed?	Achieved	The operational environment foreseen for the tactical conflict resolution service, in the context of USEPE, are the air and ground environments that comprise high densely populated areas, i.e., urban environments, or suburban environments such as industrial areas, roads or highways for entering/exiting a city. The operational environment is detailed D3.2 USEPE Initial ConOps.
OPS.V1.3	Have all stakeholders been identified, their needs and expectations for the U-space service discussed and documented?	Achieved	During the stakeholders' needs elicitation by means of an on-line questionnaire and during the first USEPE Validation Workshop, that took place on the 23rd of March 2021, participating stakeholders shared their concerns and needs that USEPE intends to take into account. When the separation method was selected, these stakeholders' needs were considered and directly influence the tactical conflict resolution service. Those needs are detailed in D3.2.
SYS.V1.1	Does the U-space service proposed architecture aligned to the U-space architecture principles?	Achieved	The architecture follows the U-space architecture principles. These principles are reflected throughout D3.2 (e.g., service-oriented, safety-focused, based on evolutionary development, etc.).
PER.V1.1	Is there a documented description (and if available qualitative evidence) of the potential impacts of the U-space service on SESAR Key Performance Areas (KPAs)?	Achieved	The validation of the USEPE Concept of Operations defines a set of success criteria, which are linked to Key Performance Indicators related with three SESAR KPA's: safety, capacity and operational efficiency. The documented description is reflected in D5.1 (USEPE VALP) and D5.2 (USEPE ER Validation Report).
PER.V1.2	Has a V1 Human Performance assessment been performed and documented?	Not Applicable	Out of USEPE scope. The concepts for tactical conflict resolution that the USEPE project aims to test are new and need a first theoretical validation phase before scaling up to human-in-the-loop simulations or real demonstrations.
PER.V1.3	Has a V1 Safety Performance assessment been performed and documented?	Not Achieved	No Safety Assessment has been developed.
PER.V1.4	Has the V1 security assessment been carried out?	Not Achieved	No Security Assessment has been developed.

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PER.V1.5	Has been a V1 environmental assessment been performed and documented?	Partially Achieved	No systematic environmental assessment was performed, but the corridor allocation criteria proposed in USEPE is expected to ensure environmental protection. Further, corridors can be beneficial to reduce noise and visual pollution in certain areas and concentrate it in those areas where the impact for citizens can be lower.
PER.V1.6	Is there any qualitative estimation or orders of magnitude of deployment costs of the U-space service?	Not Achieved	No CBA has been developed.
S&R.V1.1	Have applicable standards been identified?	Achieved	Current operational policies and constrains are identified in D3.2 (Commission Implementing Regulation (EU) 2019/947, Commission Implementing Regulation (EU) 2019/945). Also, the Commission Implementing Regulation (EU) 2021/664 is considered, where the minimum U-space mandatory and optional services are identified.
S&R.V1.2	Have needs for update/create standards been identified?	Achieved	With the existing regulations, drones cannot fly above a certain altitude either above the ground or above the highest obstacle. Up to now, they do not allow the simultaneous flight of several drones in a small area, which may be necessary in some situations. Considering USEPE's proposal, it can be seen that the current regulation falls short, so it will be necessary to adapt separation aspects to allow the development of the proposed operations and business opportunities.
TRA.V1.1	Are there recommendations proposed to be addressed during V2 related activities?	Achieved	Yes, in D5.2 topics for future research are identified. The implementation in the simulation of the resolution manoeuvres suggested by the performance-based conflict detection method would allow to analyse the domino effects produced by the tactical resolution of conflicts, since only the domino effects produced by the strategic deconfliction layer were analysed during the simulations.
VAL.V1.1	Are the relevant R&D needs identified and documented?	Achieved	Yes, key R&D needs are described in D5.1.

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VAL.V1.1	Has the project performed appropriate validation activities at V1 level to support the definition of the U-space service? E.g., fast time simulations, expert groups	Achieved	Yes, to validate the USEPE solution, three exercises (last mile delivery, emergency situations and urban surveillance) were carried out as fast-time simulations. Results are presented in D5.2.
PRG.V1.1	Have dependencies with other U-space services been identified and documented?	Achieved	Yes, for D2-C2 separation method, which involves mainly the strategic and tactical conflict resolution services, some supporting services and stakeholders are required. The interfaces to other U-space services are outlined in D3.2. (e.g., during the flight a constant tracking of the ownship position is provided by the tracking service, which allows to apply the tactical de-confliction service when necessary).

Based on the outputs of the validation results and against the criteria shown in the tables described above, it can be extracted that for both strategic and tactical conflict resolution services a V1/TRL-2 have been achieved. As a conclusion of both maturity assessments, it could be concluded that the **USEPE solution overall (the D2-C2 method) has reached a V1/TRL-2.**

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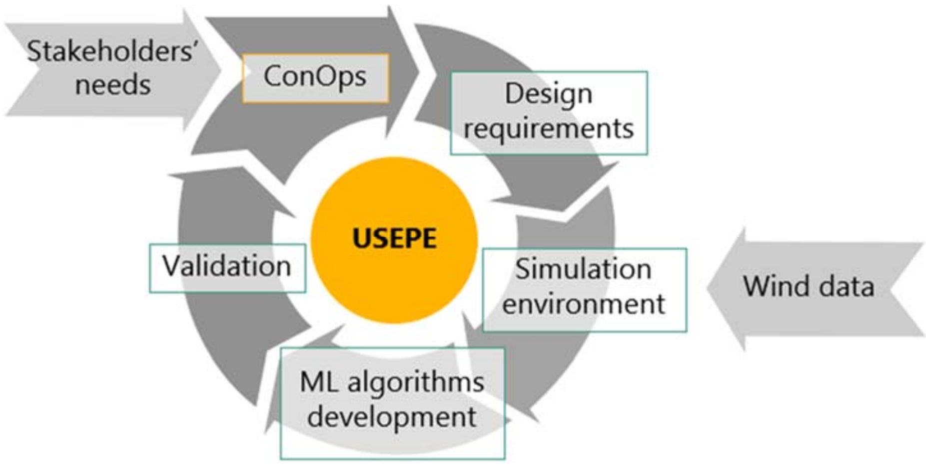
5 Conclusions

By the end of the project, USEPE will have produced 7 public technical deliverables, which are briefly described in Section 2.5. Those deliverables describe the key activities carried out during the project for the description of a new separation method (D2-C2) under a U-space environment, i.e.:

- Stakeholders' needs and requirements.
- USEPE Concept of Operations.
- Three different operational scenarios.
- System requirements.
- Validation activities.
- Machine Learning achievements.
- Wind data inclusion.

Figure 5. USEPE's key activities



As such, the conclusions for these key elements can be derived from the respective documentation.

The project's Maturity Assessment showed the full achievement of most criteria for the U-space service V1 maturity (for both strategic and tactical conflict resolution services). For this reason, the overall USEPE Solution is expected to be a V1/TRL-2 solution.

5.1 Conclusions on maturity of the SESAR Solution(s) and supporting services/capabilities

The operation of drones in VLL airspace over densely populated areas is a gradual process that builds upon the U-space services technological advances and development of associated procedures. The approach towards operations is that a large number of drones has to operate safely, avoiding collisions between them and other aircraft flying at those low altitudes, in an efficient manner while ensuring the capacity of the airspace to accommodate the number of drones. To this end, USEPE proposes the D2-C2 separation method for high densely populated areas.

USEPE Solution (the D2-C2 separation method) mainly involves the **strategic and tactical conflict resolution U-space services**, where USEPE has reached a **V1/TRL-2** maturity level on both of them. The operational environment, applicable standards, dependencies with other U-space services, the relevant R&D needs and the stakeholders have been identified during the course of the project. The impact on some of the SESAR KPA's (Safety, Capacity and Operational Efficiency) has been described and analytical tools were developed for simulation and analysis of the application. Further, the project has performed appropriate validation activities (fast-time simulations) according to the V1 level to support the definition of both U-space services.

It can be concluded that the **USEPE Solution** (D2-C2 method) has achieved a **V1/TRL-2**.

5.2 Conclusions on technical design, feasibility and architecture

USEPE focuses on the operational, procedural and technical capabilities that allow the safe separation of drones flying at VLL in densely populated environments, as urban and suburban areas in a U-space airspace. During the development of the project, USEPE has taken into consideration the U-space architecture principles [41]. Some of those principles in which USEPE focuses are:

- Service oriented architecture: a service-oriented approach shall be applied to ensure that the USEPE Solution is built based on a set of services with common characteristics (e.g., strategic and tactical de-confliction to ensure safe separation between drones).

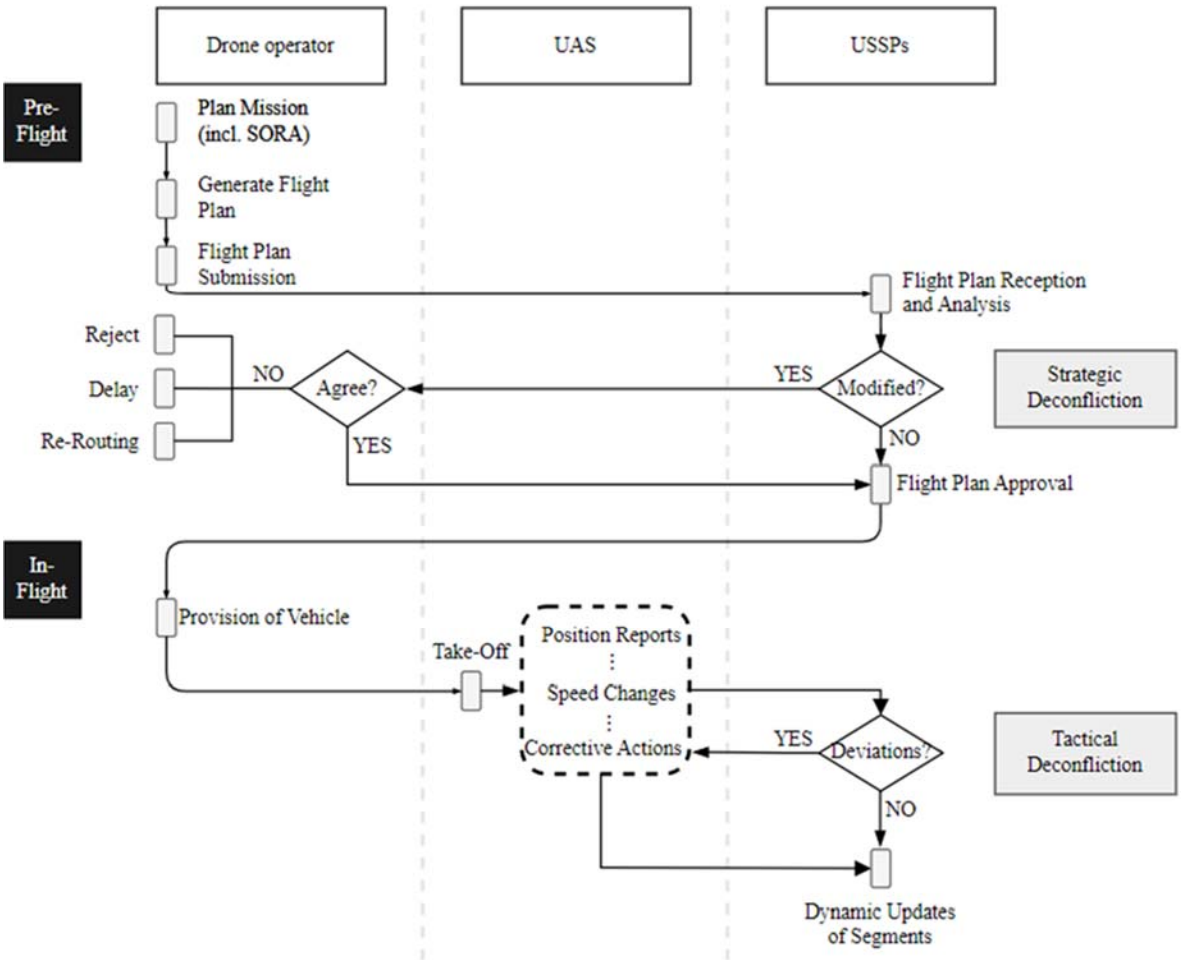
- Safety focused: the USEPE architecture has taken into full consideration the safety of its stakeholders or of other people and places that may be affected by U-space operations. The global aim of the USEPE project is to provide a safe separation in high densely populated environments.

- Technology agnostic: architecture have been described independently of the later implementation specifics (e.g., D2-C2 was developed in an Open-source simulation platform, BlueSky, for USEPE purposes, but the architecture proposed is independent to this tool).

- Based on evolutionary development (incremental approach): architecture work is an incremental and iterative process, building upon the previously consolidated baseline. In order to select the D2-C2 separation concept, a prior study based on already existing separation methods was developed.

Figure 6 shows the data flow for the different phases taken as reference in USEPE project.

Figure 6. USEPE's data flow diagram



5.3 Conclusions performance and benefit assessments

The project has obtained quantitative results regarding the **Safety** performance of the D2-C2 method. Safety was measured using the following metrics:

- KPI-USEPE-001: Number of conflicts. This metric expresses the total number of conflicts observed in all particular cases analysed.
- KPI-USEPE-002: Number of Losses of Separation. This metric expresses the total number of Losses of Separation observed in all particular cases analysed.
- KPI-USEPE-007: Ratio of conflicts per drone flight. This metric expresses the ratio between the total number of conflicts and the average number of simultaneous flights in all particular cases analysed.
- KPI-USEPE-008: Ratio of Loss of Separation per drone flight. This metric expresses the ratio between the total number of Losses of Separation and the average number of simultaneous flights in all particular cases analysed.

The project also collected quantitative results regarding the **Capacity** and **Flight Efficiency** performance of the D2-C2 method. Capacity and Flight Efficiency were measured using the following metrics:

- KPI-USEPE-003: Average Distance Flown. This metric expresses the average ground distance flown by the drones.
- KPI-USEPE-004: On-time performance. This metric expresses the quantile 0.9 of the distribution of the delay at the arrival for delivery drones when D2-C2 is applied with respect to the reference scenario.
- KPI-USEPE-005: Total Number of Flights Performed. This metric expresses the total number of completed flights. It can be accompanied with the simultaneous number of flights in the experiment.
- KPI-USEPE-006: Average flight time. This metric expresses the mean time from take-off to landing for completed flights.

The D2-C2 method effectively improved the safety metrics in all the cases analysed: reduction of number of conflicts, and reduction of Loss of Separation and near mid-air collisions events compared with the reference scenarios. This trend became more pronounced the higher the traffic density, showing that the method improves its performance as the traffic becomes more challenging, with reductions of more than a 50% of number of conflicts in the highest traffic density cases.

The reduction in conflicts was followed, in some cases, by a reduction in completed flights at the end of the simulation, due to the reduction in approved flights and the longer flight time.

For exercise 1, which simulated ordinary Zu operations, the number of completed flights was reduced by 30% compared to the reference case in the high traffic density scenario

For exercises 2 and 3, the reduction of completed flights reached a 80% of the total flights. In exercise 2 this situation can be justified by the closure of a considerable part of its airspace, while in n exercise 3 can be explained due to the restrictions in the Za airspace. Under this extraordinary situation, the total number of conflicts was deemed no longer a suitable metric for analysing safety. The ratios between conflicts and number of drones flying simultaneously allowed us to confirm that the safety metrics were improved when the total traffic was reduced due to capacity overload. As observed, those metrics presented reductions of more than 50% in all the cases analysed.

Overall, the Concept of Operations for the USEPE Solution includes features usable by U-space services and UTM (Unmanned Traffic Management) systems. The degree of demonstration in the validation is limited in some aspects, but the use cases demonstrate, directly or indirectly, that the method effectively provides improvement in the following areas:

- Audible or visual noise exposure, due to the better distribution of traffic at higher altitudes.
- Privacy and public acceptance, since the key aspects of the method are designed attending to citizen's requirements and concerns (e.g., corridors collocation in low-risk areas).
- Ground risk reduction, separation to buildings and structures, due to the previous reasons.
- Traffic load in segments close to controlled airspace.

- Integration of manned and unmanned traffic in Za and Zu airspace.

5.4 Conclusions on requirements

The template used for writing down USEPE requirements is the one proposed by the SJU, suitable for U-space requirements baseline considering Exploratory Research Projects on U-space.

In this section, a high-level picture of the conclusions extracted from the system requirements derived through the USEPE project is provided, following some of the examples stated in the U-space Consolidated Report 2019 [42]. For more information about system requirements, please refer to Appendix B of D3.2 [11].

Figure 7 shows the distribution of all the USEPE system requirements among the different SESAR categories (security, minimum performance, acceptability, interoperability and level of safety). A requirement may be allocated to more than one category. Consequently, the aggregated number of items a (188) is higher than the total number of requirements (63). This diagram identifies the categories that should be strengthened in the future. In particular, security and interoperability cateogories need to be further addressed in terms of requirements.

Figure 7. USEPE categories of requirements

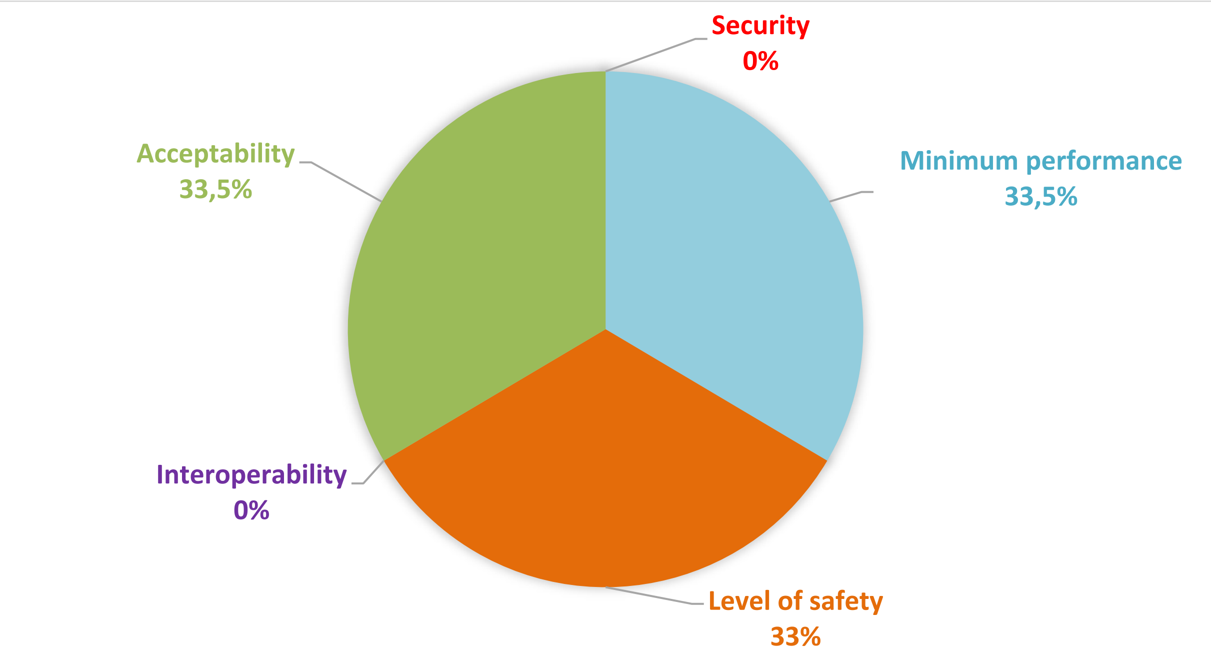
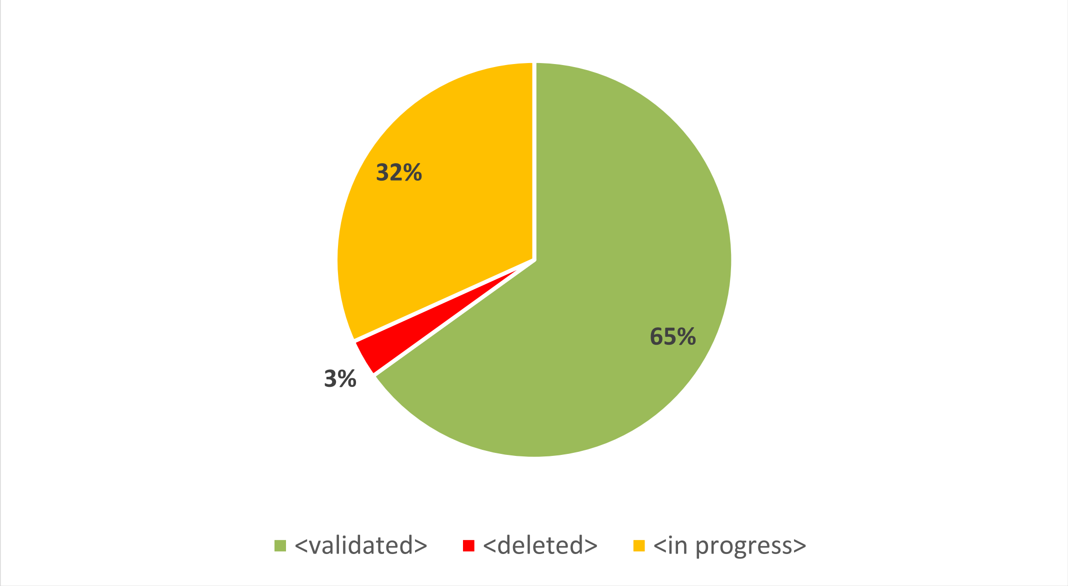


Figure 8 shows the system requirements final status. From this figure, it can be seen that most of them are validated through the simulations carried out during USEPE project. Some of them are still in progress, which must be addressed in the future. Finally, only a very few of them (two requirements) are deleted and considered not to be applicable anymore for USEPE purposes.

Figure 8. Requirements final status

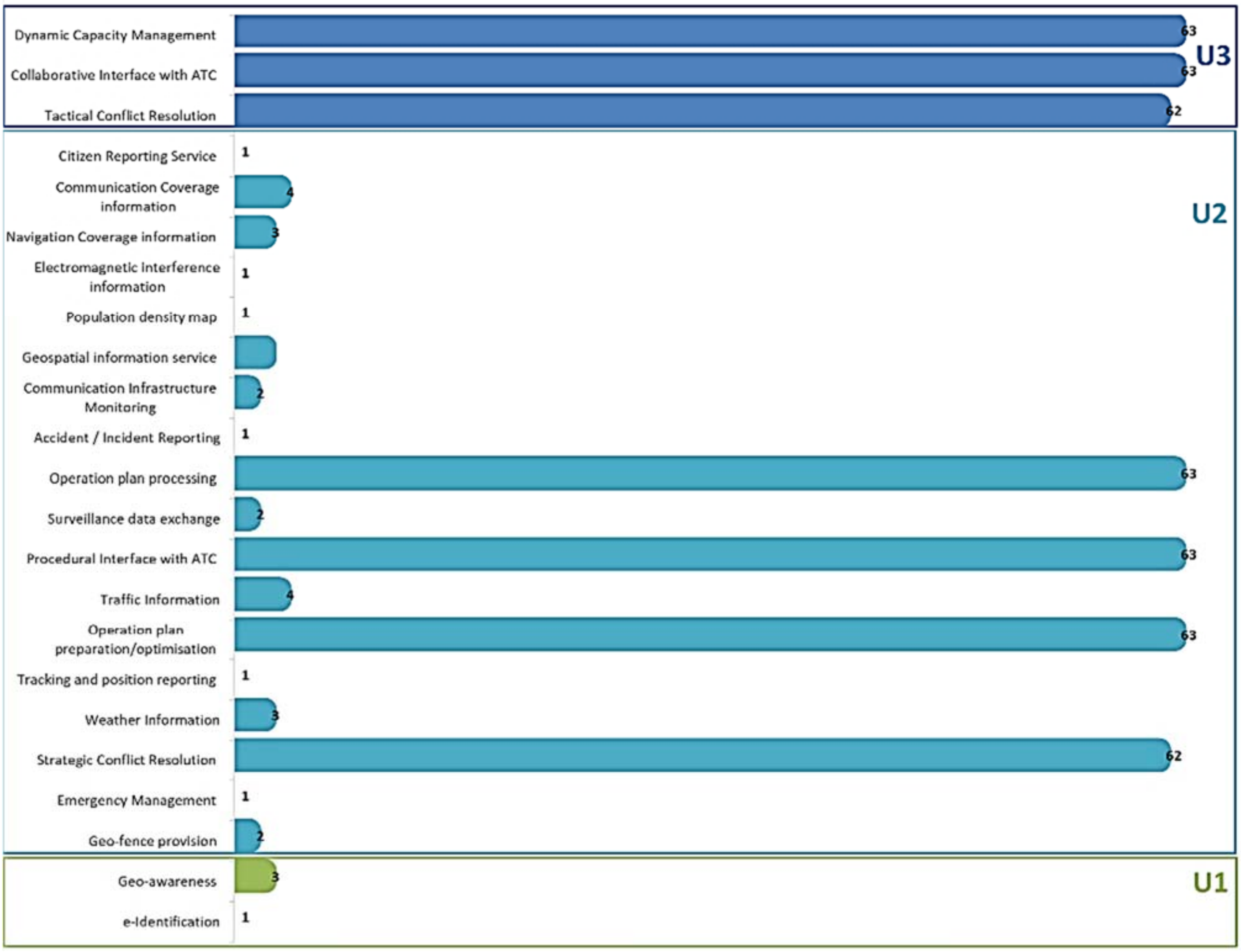


Finally, Figure 9 indicates the allocation per service. A requirement may be allocated to one or more services. Consequently, the total number of allocated requirements (472) is higher than the total number of requirements (63).

The number of requirements allocated to U1, U2 and U3 services is respectively 4, 280 and 188 (1 %, 59 % and 40 %), which reflects the intensive focus on U2 and U3 services. The project has extensively addressed some services (plan preparation/optimisation, operation plan processing, etc.) and other U-space services (those one not included in Figure 9) have not been addressed by USEPE but just assumed.

Strategic and tactical conflict resolution services, which are the main focus of USEPE, are highly considered, as shown in the figure below.

Figure 9. Number of requirements per U-space service



6 Recommendations

6.1 Recommendations for concept clarification

6.1.1 Recommendations for updating U-space services and capability definitions

USEPE project proposes the following definitions adapted to D2-C2 separation method for the strategic and tactical conflict resolution services:

Strategic conflict resolution service (CORUS Ed.3 [39] definition adapted to D2-C2)

The Strategic conflict resolution service is invoked by the Drone operation plan processing service and performed by a U-space service provider. It can be invoked because a new operation plan has been submitted or because an already submitted operation plan has changed. Strategic conflict resolution is before flight. The information provided during the strategic layer serve as an input to adapt the airspace segmentation depending on a set of rules (e.g., wind field dependency, number or frequency of conflicts in a segment, traffic dependency, events, etc.). The service has two phases. First it detects conflicts, then it proposes solutions.

Detection broadly involves examining the probabilistic 4D trajectories predicted by the Drone operation plan processing service and looking for pairs which have a reasonable probability of coming closer than is allowed in any given airspace.

In order to allow a new flight plan to enter into a segment or corridor, the strategic conflict resolution service, together with the dynamic capacity management service evaluate the proposed flights and approves them if no issues are detected. The future expected occupancy is checked, and the drone is only allowed to fly if the maximum capacity of the segments and corridors involved is not reached at any moment.

Resolution is provided as follows: if a new user is expected to enter to an overpopulated segment or corridor, the requested operation is expected to be re-routed or re-scheduled. The possible solutions are proposed to the operator who will refine the plan further before resubmitting or changing it.

Tactical conflict resolution service (CORUS Ed.3 [39] definition adapted to D2-C2)

Tactical conflict resolution is the process of resolving conflicts that occur during the flight by changing the flight while it happens and performed by a U-space service provider. The information provided during the tactical layer serve as an input to adapt the airspace segmentation depending on a set of rules (e.g., wind field dependency, number or frequency of conflicts in a segment, traffic dependency, events, etc.).

If a conflict with other drone or aircraft occurs (a loss of separation or collision course), the Tactical Conflict resolution service detects it and instructions to avoid a collision are provided.

The Tactical conflict resolution service requires that the positions of all aircraft are known and frequently updated in the airspace volume being served, and further that the precision with which these positions are known can be reliably determined. The U-space Monitoring service must be able to report deviation from planned trajectories to the Tactical conflict resolution service. Based on these tracks the *service predicts conflicts and then issues advice or instructions to aircraft with a resolution manoeuvre (e.g., change the speed, level or heading). These instructions should reach the pilot rapidly and reliably. The operator of the drone receives the command and is responsible of performing the suggested manoeuvre in both segments and corridors. The Tactical conflict resolution service can work more effectively if it makes use of a model of the flight envelope and characteristics of each aircraft concerned. Further efficiency gains may be made if the service is aware of the intention (that is the operation plan) of each flight.*

The Tactical conflict resolution service is a client of the Tracking service, the Monitoring service, the Weather information service the Drone operation plan processing service and the Drone aeronautical information management service.

6.1.2 Recommendations for updating the U-space architecture

During the development of the project, USEPE has taken into consideration the U-space architecture principles described in Section 5.2 and according to the SESAR Initial View on Principles for the U-space architecture [41]. USEPE project has not detected any deviation regarding the U-space architecture. Architecture is not the main topic addressed in USEPE, so no recommendations can be provided in this regard. Further research is needed in this topic to be able to provide future advice or guidelines.

6.1.3 Recommendations for elaboration of the U-space concept

Regarding the conflict management topic, CORUS Edition 3 [39] defines three different layers: strategic deconfliction, tactical deconfliction and collision avoidance. Further, the strategic and tactical conflict resolution services are described, but no method of providing separation is addressed.

Edition 3 of the CORUS CONOPS Annex M also collects a series of Open Issues and one of those questions is related to the separation topic:

Who should be the separator and what are the possible separation modes?

During the development of the project, USEPE has tried to answer this question and provided a new separation method. In the scope of USEPE, the separator is expected to be the USSP, through the provision of strategic and tactical deconfliction services. The separation is provided under the D2-C2 method, combining high-speed corridors, dynamic segments and geovectoring syntaxis rules.

In this method, strategic and tactical conflict resolution are performed by a U-Space Service Provider. The **separation process proposed by USEPE** is summarised as follows.

Firstly, conflicts are solved through a strategic deconfliction phase. The airspace is initially divided into segments and corridors with a maximum capacity associated, calculated as a function of the aircraft safety volumes that can fit within the segment safely and without conflicts ahead. Based on the flight plan, new users are included into those segments in accordance with the principle 'First Planned – First Served'. In order to allow a new flight plan to be approved and the vehicle associated to enter a segment or corridor, the strategic conflict resolution service, together with the dynamic capacity management service, evaluate the proposed flights and approve them if no issues are detected. The future expected occupancy is checked, and the drone is only allowed to fly if the maximum capacity of the segments and corridors involved is not reached at any moment. If a new user is expected to enter to an overpopulated segment, the requested operation is expected to be re-routed or re-scheduled.

When a conflict is not solved in a strategic deconfliction phase, due to unexpected events or disagreements between the expected flight plan and the actual path, the conflict will be tackled by the tactical layer. The performance-based conflict detection method provides the optimal resolution manoeuvre to be executed in order to resolve the conflict. The operator of the drone receives the command and is responsible of performing the suggested manoeuvre in both segments and corridors.

Emergency events are also considered in D2-C2 separation method. The access to specific segments can be banned based on specific events or flights that need special protection, such as an emergency drone or emergency manned aircraft. .

Some of the results and work performed during the validation activities have supported the refinement of the USEPE solution. The main recommendations and **areas that would need further research** in relation to the airspace structure and the separation topic are listed below:

- The placement of the corridors in the area under study will determine their final usage. It should be discussed who is in charge of defining those corridors within the city (e.g., the USSP or local authority) and suggest the criteria for locating them such as risk reduction and citizen acceptability, but also operational efficiency and maximisation of their usage.
- The initial segmentation of the airspace in the urban environment has implications on the distribution of the traffic. It should be discussed who is in charge of defining the segments and suggest some criteria for their definition such as maintaining homogeneity in terms of size, when possible, and the recommendation of dividing the segments vertically for a better distribution of the traffic, as observed in the exploration of segmentation parameters.
- The rules for segmentation updating were defined in USEPE D4.1 [13] and included the following items: wind field dependency, concentration of conflicts, traffic occupancy and emergency events. The final performance of the method depends heavily on this set of criteria. The updating did not work as well as expected during the simulations, for example during the gathering of drones in a delivery spot at the same time. The rules produced an elevated number of conflicts in that specific case. Therefore, an extension of the update rules based on those observed situations would improve D2-C2 separation.

6.2 Recommendations for standardisation and regulation

As USEPE focuses mainly on the strategic and tactical deconfliction services, for a future successful implementation of the concept, standardisation of these services is needed. To this end, USEPE proposes the following premises.

Firstly, it should be discussed who is in charge of defining the initial set, number and location of segments and corridors proposed by USEPE within the city (e.g., the government or municipality). Those responsibilities should be clearly stated in the regulation.

Then, a set of criteria for locating the segments and corridors should be defined and established in the current legal framework, taking into account at least the following factors:

- Citizen acceptability and privacy should be a relevant aspect of the regulation. Citizen consultation and co-creation is recommended in order to avoid future complains and to improve user acceptance. Engagement of transport service providers and traffic managers is necessary to design a complete Urban Air Mobility ecosystem.

- Noise and visual pollution caused by the expected increasing number of drones might be a limiting factor to the maximum separation capacity of drones. Therefore, it is necessary to provide recommendations for urban planning to include the use of drones in the urban environment. Requirement REQ-USEPE-D31-0010 could not be validated during the project, hence USEPE suggests that city authorities shall publish acceptable noise levels that will serve as an input to establish separation in order to avoid the increase of noise levels.

- Balance between demand and capacity is necessary in order to alleviate the number of drones and aircraft that can be flying simultaneously. For this purpose, during the strategical phase, the balance can be found by accommodating the number of drones asking for flying simultaneously to the capacity of the airspace at that moment. This input should be considered in the current legal framework.

- Availability of communications are impacted by the presence of buildings or objects that can shadow the link providing a loss of communications. Therefore, the urban layout and structures have to be contemplated when planning the drone operations and considered within the airspace capacity and separation during the strategical phase. In case a loss of link, due to the urban structures, occurs, then a tactical deconfliction has to be executed. Requirement REQ-USEPE-D31-0370 could not be validated, the communication coverage has been assumed in the validation phase and not simulated.

Finally, based on the project results and taking into account that the strategic and tactical deconfliction services are not included in Regulation 2021/664 [43], USEPE proposes the following preliminary descriptions:

Strategic conflict resolution service (USEPE proposal)

1. *The strategic conflict resolution service shall be provided by the U-space service provider and shall enable the UAS operators to obtain a conflict free flight plan in nominal conditions for the entire duration of the flight and shall:*
   - *(a) consider dynamic changes within the airspace and update the segments accordingly*
   - *(b) be able to handle prioritised flights*
   - *(c) be able to handle accurate wind data*
   - *(d) Establish a reasonable frequency to update the segments*
2. *The USSP will determine under which circumstances the flight plan must be re-routed or re-scheduled once the flight has commenced. This will include under which special circumstances vehicles should request permission to enter segments and corridors after the flight plan has been changed.*

Tactical conflict resolution service (USEPE proposal)

1. *The tactical conflict resolution service shall be provided by the U-space service provider in a way that:*
   - *(a) The operator is provided with the optimal manoeuvre according to its performances*
   - *(b) The manoeuvre does not imply cascade effects, leading to more conflicts ahead*
   - *(c) The number of segmentation updates is minimal*

2. *Upon receiving the tactical conflict resolution advice from the U-space service provider, UAS operators shall take immediate action to avoid any collision.*

6.3 Recommendations for further R&D needs

UAM represents one of the most demanding/challenging use cases for U-space services and capabilities and it will require an extensive set of R&D and validation activities before its full deployment. The SESAR 2020 is an innovation programme designed for researching the future traffic management in Europe, made up of three main research strands: exploratory research, industrial research and validation and very large-scale demonstrations. These strands have been designed as an innovation pipeline through which ideas are transformed into tangible solutions for industrialization.

Although the research carried out in USEPE and other SESAR related projects has largely improved the knowledge on safety separation management of drones, some more research is needed in the future. In order to continue in this R&D endeavour and progress in the innovation pipeline, three main research lines are identified: the first one related to the D2-C2 method itself, the second one related to the USEPE Maturity Assessment, and the last one related to future contribution to the Digital European Sky calls.

Full city-wide simulation based on D2-C2 method

The implementation of the D2-C2 method in the BlueSky simulator has required a set of assumptions for performing the validation exercises. Although it was clarified that the reliability of the validations was not undermined due to those limitations, it was agreed that the scope of USEPE could have been broader if the study would have added more layers of realism. It is recommended to look into detail on the following topics for potential future research in the USEPE research line:

- The dynamic update segmentation service depends on a set of parameters. They were explored to provide optimal results in terms of safety (conflict reduction) for the cases that concerned this validation report. A thorough exploration of the implications of those parameters in the KPAs analysed and the addition of more case studies would provide useful insight on the mechanisms that emerge with these update rules.
- The study of contingency situations in more detail would provide insight on the correct procedures to be incorporated to the concept when non-nominal situations occur and on how to identify those situations well in advance in order to anticipate to their effects.
- The human factors and their implication in the operations should become an important research line. In particular, the communication methods between drone operators, USSPs and the D2-C2 method and the required times for conflict warning, segment change notification, etc.
- The implementation in the simulation of the resolution manoeuvres suggested by the performance-based conflict detection method would allow a better analysis of the domino effects produced by the tactical resolution of conflicts. USEPE has only studied the domino effects produced by the strategic deconfliction layer.
- Due to performance limitations of the simulator (and the massive computing time needed to accomplish a large scale simulation), a full city-wide simulation was not performed (the

exercises were concentrated on small portions of the city of Hannover– focusing on a few flights playing the main role, considering only the local weather conditions affecting those small portions of the city) . It should be further studied how well the D2-C2 segments and corridors can be applied to a complete city, a complete traffic distribution (not only the flights singled out in USEPE exercises) and a complete picture of the wind data for the whole city.

Further R&D activities for USEPE V1 maturity

In order to complete all the V1 U-space service maturity criteria, several activities have been identified that would have needed to be performed:

- A primary Safety Performance Assessment in conformance with the SESAR Safety Reference Material
- A primary Security Risk Assessment in conformance with the SESAR Security Reference Material.
- A Complete environmental assessment following SESAR Environmental Reference Material.
- A full Cost Benefit Analysis following V1 guidance material
- A full Description of the Solution and Operational Improvement Steps (OIs) to be added to EATMA (European Air Traffic Management Architecture).
- A dedicated standardisation Activity.

Future potential contribution

As declared in the European ATM Master Plan, *"Roadmap for the safe integration of drones into all classes of airspace, the drone marketplace is estimated at a value above 10 billion euros annually".* Most of drones' applications will be oriented towards a diverse variety of business which impact on the whole airspace ranging from controlled to uncontrolled in rural, sub-urban and urban areas. Therefore, this estimated marketplace from drones require to adopt quick and efficient measures to allow the return on investment as soon as possible while ensuring that drone operations, in any environment, are as safe as possible avoiding potential conflicts and loss of separation between the large amount of drones flying.

The USEPE Consortium has identified some of the topics in the Digital European Sky Exploratory Research 01 calls (HORIZON-SESAR-2022-DES-ER-01) and Digital European Sky Industrial Research 01 calls (HORIZON-SESAR-2022-DES-IR-01), as potential steps forward for the research outcomes of the project (i.e., future project that may potentially benefit of and build upon the results of USEPE):

- Fundamental Science and Outreach for U-space and Urban Air Mobility (HORIZON-SESAR-2022-DES-ER-01-WA1-3).
- ATM application-oriented Research for U-space and Urban Air Mobility (HORIZON-SESAR-2022-DES-ER-01-WA2-4).
- Industrial Research & Validation for Artificial Intelligence for Aviation (HORIZON-SESAR-2022-DES-IR-01-WA3-4).
- Fast Track Innovation and Uptake U-space and Urban Air Mobility (HORIZON-SESAR-2022-DES-IR-01-WA4-1).

7 References

7.1 Project Deliverables

[1] USEPE. (2021). *D1.1 H-Requirement No. 1, Edition 00.01.01, 22 April 2021.*

[2] USEPE. (2021). *D1.2 POPD-Requirement No. 2, Edition 00.01.00, 10 February 2021.*

[3] USEPE. (2021). *D1.3 POPD-Requirement No. 3, Edition 00.01.02, 01 July 2021.*

[4] USEPE. (2021). *D2.1 USEPE Project Management Plan, Edition 00.01.02, 11 March 2022.*

[5] USEPE. (2021). *D2.2 USEPE First Project Report, Edition 00.01.00, 09 July 2021.*

[6] USEPE. (2022). *D2.3 USEPE Final Project Results Report, Edition 00.01.00, 25 November 2022.*

[7] USEPE. (2021). *D2.4 USEPE Data Management Plan, Edition 00.01.00, 30 June 2021.*

[8] USEPE. (2022). *D2.5 USEPE Second Project Report, Edition 00.01.00, 30 June 2022.*

[9] USEPE. (2022). *D2.6 USEPE Communication, Dissemination and Exploitation Plan, Edition 00.02.00, 11 February 2022.*

[10] USEPE. (2021). *D3.1 USEPE Concept of Operations Outline, Edition 00.01.00, 30 June 2021.*

[11] USEPE. (2022). *D3.2 USEPE Initial Concept of Operations, Edition 00.00.01, 31 October 2022.*

[12] USEPE. (2022). *D3.3 USEPE Consolidated Concept of Operations, Edition 00.00.01, 23 December 2022.*

[13] USEPE. (2022). *D4.1 Report on design concepts implementation. Edition 00.01.00, 31 August 2022.*

[14] USEPE. (2022). *D4.2 Report on Machine Learning Algorithms, Edition 00.01.00, 31 October 2022.*

[15] USEPE. (2021). *D5.1 USEPE Validation Plan, Edition 00.01.00, 31 October 2021.*

[16] USEPE. (2022). *D5.2 USEPE Exploratory Reseach Validation Plan, Edition 00.01.00, 16 November 2022.*

[17] USEPE. (2022). *D6.1 Communication, Dissemination Activities Report, Edition 00.01.00, 15 December 2022.*

7.2 Project Publications

7.2.1 Publications at conferences and in journals

Outcomes of the USEPE project led to several publications to journal and conferences. They are listed as below:

[18] Shivakoti, Sandeep; Arntzen, Aurilla Aurelie; Güldal, Serkan; Nistal Cabañas, Esther. Drone Operations and Communications in an Urban Environment. I: Sensordevices 2021: The Twelfth International Conference on Sensor Device Technologies and Applications. International Academy, Research and Industry Association (IARIA) 2021 ISBN 978-1-61208-918-8. s. 13-18

[19] Scientific paper Sebastian Giersch, Omar El Guernaoui, Siegfried Raasch, Manuela Sauer, Marta Palomar, "Atmospheric flow simulation strategies to assess turbulent wind conditions for safe drone operations in urban environments," Journal of Wind Engineering and Industrial Aerodynamics, Volume 229, 2022, ISSN 0167-6105

[20] R. Komatsu, A. A. A. Bechina, S. Güldal and M. Şaşmaz, "Machine Learning Attempt to Conflict Detection for UAV with System Failure in U-Space: Recurrent Neural Network, RNN," 2022 International Conference on Unmanned Aircraft Systems (ICUAS), 2022, pp. 78-85, doi: 10.1109/ICUAS54217.2022.9836147.

[21] O. H. Dahle, J. Rydberg, M. Dullweber, N. Peinecke and A. A. A. Bechina, "A proposal for a common metric for drone traffic density," 2022 International Conference on Unmanned Aircraft Systems (ICUAS), 2022, pp. 64-72, doi: 10.1109/ICUAS54217.2022.9836143.

[22] A. A. A. Bechina et al., "A Model for a Safer Drone's Operation in an Urban Environment," 2022 International Conference on Unmanned Aircraft Systems (ICUAS), 2022, pp. 73-77, doi: 10.1109/ICUAS54217.2022.9835715.

[23] N. Peinecke, "How to stay well clear in corridors and swarms: Detect-and-avoid ranges for geovectoring concepts," 2022 International Conference on Unmanned Aircraft Systems (ICUAS), 2022, pp. 57-63, doi: 10.1109/ICUAS54217.2022.9836220.

[24] Project website, https://usepe.eu/

7.2.2 Presentations at conferences

[25] POLIS Annual conference 2021, Gothenburg: "USEPE: U-Space Separation in Europe", December 2021, Publication

[26] Nordic Edge Expo 2022, Stavanger: "USEPE: U-Space Separation in Europe", May 2022, Publication

[27]USEPE Workshop ICUAS'22: "U-space for the future urban aerial mobility: opportunities and challenges", June 2022, Publication

[28] USEPE Workshop ICUAS'22: "A review of approaches for evaluating Drone traffic densities", June 2022, Publication

[29] USEPE Workshop ICUAS'22: "A new separation approach for a safer drones' operations in densely populated areas", June 2022, Scientific Paper

[30] USEPE Workshop ICUAS'22: "Turbulent wind field simulation data as input for BlueSky traffic simulator", June 2022, Publication

[31] USEPE Workshop ICUAS'22: "USEPE, U-space SEParation in Europe", June 2022, Publication

[32] USEPE Workshop ICUAS’22: “How to stay well clear in corridors and swarms: Detect-and-avoid ranges for geovectoring concepts”, June 2022, Publication

[33] USEPE Workshop ICUAS’22: “An implementation in BlueSky of a novel Concept of Operation”, June 2022, Publication

[34] USEPE Workshop ICUAS’22: “UAV path planning in search and rescue (SAR) missions”, June 2022, Publication

[35] USEPE Workshop ICUAS’22: “Can Artificial Intelligence be a good approach to a safe drone operation in an urban environment?” June 2022, Publication

[36] USEPE Workshop ICUAS’22: “The role of local authorities in urban air mobility”, June 2022, Publication

[37] POLIS Annual Conference 2022, Brussels: “USEPE: U-Space Separation in Europe”, December 2022, Publication

7.3 Other

[38] European ATM Master Plan

[39] U-space CONOPS Edition 3

[40] Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft

[41] Initial view on Principles for the U-space architecture https://www.sesarju.eu/sites/default/files/documents/uspace/SESAR%20principles%20for%20U-space%20architecture.pdf

[42] Consolidated report on SESAR U-space research and innovation results https://www.sesarju.eu/news/consolidated-report-sesar-u-space-research-andinnovationresults

[43] Commission Implementing Regulation (EU) 2021/664 of 22 April 2021 on a regulatory framework for the U-Space

[44] ICAO, «Remotely Piloted Aircraft Systems (RPAS) Concept of Operations for International IFR Operations», 2017

[45] ICAO, «Doc 10019. Manual on Remotely Piloted Aircraft Systems. 1st Edition», 2015

Appendix A Standardisation & regulation

A.1 Glossary of terms

Table 9. Glossary

Term	Definition	Source of the definition
BVLOS operation	Beyond visual line-of-sight (BVLOS) operation. An operation in which the remote pilot or RPA observer does not use visual reference to the remotely piloted aircraft in the conduct of flight.	ICAO RPAS CONOPS for international IFR Operations [44]
Remote pilot	A person charged by the operator with duties essential to the operation of a remotely piloted aircraft and who manipulates the flight controls, as appropriate, during flight time.	ICAO Doc 10019: Manual on Remotely Piloted Aircraft Systems (RPAS) [45]
UAS	Unmanned Aircraft System. Any aircraft and related systems without a pilot on board, either remotely piloted or autonomous.	N/A
U-space airspace	UAS geographical zone designated by Member States, where UAS operations are only allowed to take place with the support of U-space services.	COMMISSION IMPLEMENTING REGULATION (EU) 2021/664 of 22 April 2021 on a regulatory framework for the U-space [43]
U-space service	Service relying on digital services and automation of functions designed to support safe, secure and efficient access to U-space airspace for a large number of UAS.	COMMISSION IMPLEMENTING REGULATION (EU) 2021/664 of 22 April 2021 on a regulatory framework for the U-space [43]
VLOS operation	Visual line-of-sight (VLOS) operation. An operation in which the remote pilot or RPA observer maintains direct unaided visual contact with the remotely piloted aircraft.	ICAO RPAS CONOPS for international IFR Operations [44]

A.2 Acronyms and Terminology

Table 10. Acronyms and technology

Term	Definition
AGL	Above Ground Level
AHP	Analytic Hierarchy Process
AI	Artificial Intelligence

Term	Definition
ATC	Air Traffic Control
ATM	Air Traffic Management
ATS	Air Traffic Services
BVLOS	Beyond Visual Line of Sight
CBA	Cost Benefit Analysis
ConOps	Concept of Operations
CTR	Controlled Traffic Region
D2-C2	Dynamic Density Corridor Concept
EASA	European Aviation Safety Agency
EATMA	European Air Traffic Management Architecture
GSS	General Separation Score
HAJ	Hannover Airport
KPA	Key Performance Area
KPI	Key Performance Indicator
LSS	Local Separation Score
ML	Machine Learning
OIs	Operational Improvement Steps
PSS	Pairwise Separation Score
SESAR	Single European Sky ATM Research Programme
S3JU	SESAR 3 Joint Undertaking (Agency of the European Commission)
TRL	Technology Readiness Level
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
USEPE_ML	USEPE Machine Learning algorithm
USSP	U-Space Service Provider
UTM	Unmanned Traffic Management
VLL	Very Low Level
VLOS	Visual Line of Sight
WAC	World ATM Congress
WP	Work Package

Appendix B Requirements

Table 11. USEPE Requirements

Identifier	Title	Requirement	Status	Rationale	CAT-PER	CAT-SAF	CAT-ACC	**U-space Service name** (Foundation package service (U-space CONOPS Ed3) linked to Reg. (EU) 2021/664 (EASA service mandatory & EASA service mandatory depending on member state))																						
								e-Identification (U1)	Geo-awareness (U1) ** Geo-awareness	Geo-fence provision (incl. dynamic geo-fencing) (U2) ** Geo-awareness	Emergency Management (U2) **** Traffic Information ** Conformance monitoring	Strategic Conflict Resolution (U2) *** UAS flight authorization	Weather Information (U2) * Weather information	Tracking and position reporting (U2) * Network identification **** Traffic Information	Operation plan preparation/optimisation (U2)	Traffic Information (U2) * Network identification **** Traffic Information	Procedural Interface with ATC (U2)	Surveillance data exchange (U2) * Network identification	Operation plan processing (U2) *** UAS flight authorization	Accident / Incident Reporting (U2)	Communication Infrastructure Monitoring (U2)	Geospatial information service (U2)	Population density map (U2)	Electromagnetic interference information (U2)	Navigation Coverage information (U2)	Communication Coverage information (U2)	Citizen Reporting Service (U2)	Tactical Conflict Resolution (U3)	Collaborative Interface with ATC (U3)	Dynamic Capacity Management (U3)
REQ-USEPE-D31-0001	Maximum noise levels	The separation method used for separation management shall be able to accept maximum noise levels.	<in progress>	The noise produced by drones may annoy the citizens. City authorities shall publish acceptable noise levels that will serve as an input to establish separation in order to avoid the increase of noise levels.	X		X					X			X		X		X									X	X	X
REQ-USEPE-D31-0002	Cooperative manned aircraft performance	The separation method used for separation management shall be able to consider the performance of cooperative	<validated>	The integration of drones in the airspace may interfere with the performance of cooperative manned aircraft. Separation methods shall maintain safety distance with	X	X	X					X			X		X		X									X	X	X

		manned aircraft.		cooperative manned aircrafts that will serve as an input to establish separation in order to avoid conflicts.																										
REQ-USEPE-D31-0003	Number of cooperative manned aircraft	The separation method used for separation management shall be able to accept the number of cooperative manned aircraft flying.	<validated>	The integration of drones in the airspace may interfere with the number of cooperative manned aircrafts flying. Separation methods shall maintain safety distance with all the aircrafts flying in order to integrate drones into the airspace.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0004	Type of cooperative manned aircraft	The separation method used for separation management shall be able to accept the different types of flights (VFR or IFR) of cooperative manned aircraft.	<in progress>	The integration of drones in the airspace may interfere with the different types of flights of cooperative manned aircrafts. In order to integrate them into the airspace they shall be able to maintain separation with cooperative manned aircrafts IFR and VFR flights.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0005	Non-cooperative manned aircraft performance	The separation method used for separation management shall be able to consider the performance of non-cooperative manned aircraft.	<in progress>	The integration of drones in the airspace may interfere with the performance of non-cooperative manned aircrafts. Separation methods shall maintain safety distance with non-cooperative manned aircrafts that will serve as an input to establish separation in order to avoid conflicts.	X	X	X					X			X		X		X									X	X	X

REQ-USEPE-D31-0006	Type of non-cooperative manned aircraft	The separation method used for separation management shall be able to accept the different types of flights (VFR or IFR) of non-cooperative manned aircraft.	<in progress>	The integration of drones in the airspace may interfere with the different types of flights of non-cooperative manned aircrafts. In order to integrate them into the airspace they shall be able to maintain separation with non-cooperative manned aircraft IFR and VFR flights.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0007	Number of non-cooperative manned aircraft	The separation method used for separation management shall be able to accept the number of non-cooperative manned aircraft flying.	<in progress>	The integration of drones in the airspace may interfere with the number of non-cooperative manned aircrafts flying. Separation methods shall maintain safety distance with all the aircrafts flying in order to integrate drones into the airspace.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0008	Air Traffic Control instructions	The separation method used for separation management shall be able to accept Air Traffic Control instructions as long as they are commensurate with ATC role in the portion of airspace concerned (Zu).	<in progress>	Some indications are needed in order to organize the air traffic flow. Air Traffic Controllers give instructions that will serve as an input to establish separation in order to avoid conflicts.	X	X	X					X			X		X		X									X	X	X

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REQ-USEPE-D31-0009	Air Traffic Control clearances	The separation method used for separation management shall be able to accept Air Traffic Control clearances as long as they are commensurate with ATC role in the portion of airspace concerned Zu.	<in progress>	Authorizations are needed in order to organize the air traffic flow. Air Traffic Controllers give clearances that will serve as an input to establish separation in order to avoid conflicts.	X	X	X					X			X		X		X								X	X	X
REQ-USEPE-D31-0010	Separation provided by Air Traffic Control	The separation method used for separation management shall be able to accept the separation provided by Air Traffic Control in the portion of airspace concerned (Zu).	<in progress>	Separation instructions depending on the conditions of the environment are needed in order to organize the air traffic flow. Air Traffic Controllers provide separation that will serve as an input to establish separation between the users in order to avoid conflicts.	X	X	X					X			X	X	X		X								X	X	X
REQ-USEPE-D31-0011	Service provided by Air Traffic Control	The separation method used for separation management shall be able to accept the service provided by Air Traffic Control in the portion of airspace concerned (Zu).	<deleted>	Control services are needed in order to organize the flow of air traffic. Air Traffic Controllers provide service that will serve as an input to establish separation in order to prevent collisions.	X	X	X					X			X	X	X		X								X	X	X
REQ-USEPE-D31-0012	Speed limitation of each airspace class	The separation method used for separation management shall be able to accept the speed limitation	<validated>	Drones will flight in the different classes of the airspace. Each airspace class shall have an acceptable speed limitation that will serve as an input to establish	X	X	X					X			X		X		X								X	X	X

		of each airspace class.		the necessary speed requirements.																										
REQ-USEPE-D31-0013	Radio communication capabilities of each airspace class	The separation method used for separation management shall be able to consider the radio communication capabilities of each airspace class.	<in progress>	Drones will flight in the different classes of the airspace. Drones shall use the radio communication capabilities of each airspace class that will serve as an input to establish separation in order improve the interaction between the different users.	X	X	X					X			X		X		X							X		X	X	X
REQ-USEPE-D31-0014	Intensity and magnitude of the turbulent wind	The separation method used for separation management shall be able to accept intensity and magnitude of the turbulent wind.	<validated>	Intensity and magnitude of the turbulent wind changes over time. This is a problem to consider that will serve as an input to establish separation in order to avoid loss of distance between the users due to these fluctuations.	X	X	X					X	X		X		X		X									X	X	X
REQ-USEPE-D31-0015	Initial airspace capacity	The separation method used for separation management shall be able to accept the initial airspace capacity calculated before the conflicts.	<validated>	Airspace has an initial capacity which determines the number of drones that can flight in it. This is a limitation to consider that will serve as an input to establish separation in order to avoid overload of drones.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0016	Percentage of daylight	The separation method used for separation management shall be able to accept the available percentage of daylight.	<in progress>	The available percentage of daylight is constantly changing. This is a problem to consider that will serve as an input to establish separation in order to avoid conflicts at night or when there is little light available.	X	X	X					X			X		X		X									X	X	X

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REQ-USEPE-D31-0017	Conflicts at strategic phase per hour and per volume unit	The separation method used for separation management shall be able to accept the number of conflicts at strategic phase per hour and per volume unit.	<validated>	During the strategic phase conflicts may arise. This is a problem to consider that will serve as an input to establish separation in order to solve all the unexpected conflicts during the strategic phase.	X	X	X					X			X		X		X										X	X
REQ-USEPE-D31-0018	Conflicts at tactical phase per hour and per volume unit	The separation method used for separation management shall be able to accept the number of conflicts at tactical phase per hour and per volume unit.	<validated>	During the tactical phase conflicts may arise. This is a problem to consider that will serve as an input to establish separation in order to be able to solve all the unexpected conflicts during the tactical phase.	X	X	X								X		X		X									X	X	X
REQ-USEPE-D31-0019	Command link availability	The separation method used for separation management shall be able to consider the command link availability.	<validated>	Due to the presence of obstacles in the urban and suburban environment command link availability can change. This is a problem to consider that will serve as an input to establish separation in order to avoid the loss of communication.	X	X	X					X			X		X		X		X				X	X		X	X	X
REQ-USEPE-D31-0020	Control link availability	The separation method used for separation management shall be able to consider the control link availability.	<validated>	Due to the presence of obstacles in the urban and suburban environment control link availability can change. This is a problem to consider that will serve as an input to establish separation in order to avoid the loss of control.	X	X	X					X			X		X		X		X				X	X		X	X	X

REQ-USEPE-D31-0021	Identification of drones flying	The separation method used for separation management shall be able to accept the identification of drones flying.	<validated>	Each drone shall have an identification. This is information to consider that will serve as an input to establish separation in order to identify all drones flying in the airspace.	X	X	X	X				X			X		X		X									X	X	X
REQ-USEPE-D31-0022	Wind information	The separation method used for separation management shall be able to accept swind information.	<validated>	Meteorology affects the way a drone can fly. This is a problem to consider that will serve as an input to establish separation in order to avoid conflicts due to adverse wind conditions.	X	X	X					X	X		X		X		X									X	X	X
REQ-USEPE-D31-0023	Emergencies information	The separation method used for separation management shall be able to accept emergencies information.	<validated>	Emergencies may occur during the flight. The emergencies information will serve as an input to establish separation in order to separate drones from an emergency flight.	X	X	X				X	X			X		X		X	X							X	X	X	X
REQ-USEPE-D31-0024	Geofence restrictions	The separation method used for separation management shall be able to accept geofence restrictions.	<validated>	The environment establishes some geofence restrictions. This is a boundary to consider that will serve as an input to establish separation in order to protect drones from obstacles.	X	X	X		X	X		X			X		X		X			X						X	X	X
REQ-USEPE-D31-0025	Flight restrictions	The separation method used for separation management shall be able to accept flight restrictions.	<validated>	During a flight there may be some restrictions. This is a boundary to consider that will serve as an input to establish separation in order to protect drones from dangers and obstacles.	X	X	X		X			X			X		X		X			X						X	X	X

REQ-USEPE-D31-0026	Tracking information	The separation method used for separation management shall be able to accept tracking information.	<validated>	Tracking information is essential to locate drones. This is information to consider that will serve as an input to establish separation in order to locate drones in the airspace.	X	X	X					X		X	X		X		X									X	X	X
REQ-USEPE-D31-0027	Electromagnetic interference information	The separation method used for separation management shall be able to accept electromagnetic interference information.	<in progress>	Electromagnetic interference may occur during the flight. This is a problem to consider that will serve as an input to establish separation in order to avoid conflicts due to these interferences.	X	X	X					X			X		X		X					X				X	X	X
REQ-USEPE-D31-0028	Authorization of the operation plan	The separation method used for separation management shall be able to accept the authorization of the operation plan.	<validated>	Authorization is needed in order to process the operation plan. This authorization will serve as an input to establish separation in order to be able to process all the operation plans.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0029	Conformance monitoring alerts	The separation method used for separation management shall be able to accept conformance monitoring alerts.	<validated>	Conformance monitoring alerts may occur during the flight. This is information to consider that will serve as an input to establish separation in order to avoid conflicts due to unexpected issues or emergencies.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0030	Wind monitoring alerts	The separation method used for separation management shall be able to accept wind monitoring alerts.	<validated>	Wind monitoring alerts may occur during the flight. This is information to consider that will serve as an input to establish separation in order to avoid conflicts due to adverse wind conditions.	X	X	X					X	X		X		X		X									X	X	X

REQ-USEPE-D31-0031	Ground risk alerts	The separation method used for separation management shall be able to accept ground risk alerts.	<validated>	Ground risk alerts may occur during the flight. This is information to consider that will serve as an input to establish separation in order to avoid dangerous situations with citizens or buildings.	X	X	X		X	X		X			X		X		X									X	X	X
REQ-USEPE-D31-0032	Traffic information	The separation method used for separation management shall be able to accept traffic information.	<validated>	Traffic information is essential for the operation safety. This information will serve as an input to establish separation in order to be aware of the traffic situation at all times.	X	X	X					X			X	X	X		X									X	X	X
REQ-USEPE-D31-0033	Drone aeronautica l information	The separation method used for separation management shall be able to accept drone aeronautical information.	<validated>	Drone aeronautical information provides data to the geo-fencing services as well as operational planning preparation service. This information will serve as an input to establish separation in order to be aware of the drone situation at all times.	X	X	X					X			X	X	X		X									X	X	X
REQ-USEPE-D31-0034	Geospatial information	The separation method used for separation management shall be able to accept geospatial information.	<validated>	Geospatial information gives awareness of the environment. This information will serve as an input to establish separation in order to be aware of the obstacles and dangers in the urban and suburban environment.	X	X	X					X			X		X		X			X						X	X	X
REQ-USEPE-D31-0035	Population density	The separation method used for separation management shall be able to accept the	<validated>	Population density gives awareness of the number of people in each surface unit. This information will serve as an input to establish separation in order to be	X	X	X					X			X		X		X				X					X	X	X

		population density.		aware of the danger they can cause to people.																										
REQ-USEPE-D31-0036	Navigation coverage information	The separation method used for separation management shall be able to accept the navigation coverage information.	<in progress>	Navigation coverage may not be good throughout the flight. This information will serve as an input to establish separation in order to be aware of whether there is a loss of navigation coverage.	X	X	X					X			X		X		X						X			X	X	X
REQ-USEPE-D31-0037	Communication coverage information	The separation method used for separation management shall be able to accept the communication coverage information.	<in progress>	Communication coverage may not be good throughout the flight. This information will serve as an input to establish separation in order to be aware of whether there is a loss of communication coverage.	X	X	X					X			X		X		X							X		X	X	X
REQ-USEPE-D31-0038	Surveillance data	The separation method used for separation management shall be able to accept surveillance data.	<in progress>	Surveillance data will be provided during the flight. This information will serve as an input to establish separation in order to be aware of whether there is an unexpected danger or some unforeseen.	X	X	X					X			X		X	X	X									X	X	X
REQ-USEPE-D31-0039	Limit in safety levels	The separation method used for separation management shall be able to accept a limit in safety levels.	<validated>	Acceptable safety levels are necessary for the integration of drones into the airspace. These boundaries shall be published and will serve as an input to establish separation in order to have a limit in the levels of safety.	X	X	X					X			X		X	X	X									X	X	X
REQ-USEPE-D31-0040	Drones' speed	The separation method used for separation management shall be able to	<validated>	Drone speed depends on its performance and capabilities. This information will serve as an input to establish	X	X	X					X			X		X		X									X	X	X

		accept drones' speed.		separation in order to ensure that drones can carry out the operation.																										
REQ-USEPE-D31-0041	Drones' volume	The separation method used for separation management shall be able to accept drones' volume.	<validated>	Drone volume depends on its geometry and size. This information will serve as an input to establish separation in order to ensure that drones will not collide with other users.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0042	Drones' climb rate	The separation method used for separation management shall be able to accept drones' climb rate.	<validated>	Drone climb rate is the positive rate of altitude change with respect to time. This information will serve as an input to establish separation in order to ensure that drones will be able to meet the performance requirements.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0043	Drones descend rate	The separation method used for separation management shall be able to accept drones descend rate.	<validated>	Drone descend rate is the negative rate of altitude change with respect to time. This information will serve as an input to establish separation in order to ensure that drones will be able to meet the performance requirements.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0044	Drones manoeuvrability	The separation method used for separation management shall be able to accept drones manoeuvrability.	<validated>	Drone manoeuvrability is the quality of being easy to move or steer while in motion. This information will serve as an input to establish separation in order to ensure that drones will be able to meet the performance requirements.	X	X	X					X			X		X		X									X	X	X

REQ-USEPE-D31-0045	Drones' navigation performance	The separation method used for separation management shall be able to accept drones' navigation performance.	<in progress>	Drone navigation performance depends on the drone's equipment. This information will serve as an input to establish separation in order to ensure that drones will be able to meet the performance requirements.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0046	Number of existing corridors	The separation method used for separation management shall be able to accept the number of existing corridors.	<validated>	In order to separate drones with different capabilities there will be different corridors. This number of corridors will serve as an input to establish separation in order to ensure that drones will fly in those that suit their capabilities.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0047	Corridors altitude	The separation method used for separation management shall be able to accept the corridors altitude.	<validated>	In order to separate drones with different capabilities the altitude of the corridors will change. The corridors altitude will serve as an input to establish separation in order to ensure that drones will fly in those that suit their capabilities.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0048	Corridors maximum speed	The separation method used for separation management shall be able to accept the corridors maximum speed.	<validated>	In order to separate drones with different capabilities the corridors maximum speed will change. The corridors maximum speed will serve as an input to establish separation in order to ensure that drones will fly in those that suit their capabilities.	X	X	X					X			X		X		X									X	X	X

REQ-USEPE-D31-0049	Corridors minimum speed	The separation method used for separation management shall be able to accept the corridors minimum speed.	<in progress>	In order to separate drones with different capabilities the corridors minimum speed will change. The corridors minimum speed will serve as an input to establish separation in order to ensure that drones will fly in those that suit their capabilities.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0050	Corridors heading	The separation method used for separation management shall be able to accept the corridors heading.	<validated>	In order to separate drones with different capabilities the corridors heading will change. The corridors heading will serve as an input to establish separation in order to ensure that drones will fly in those that suit their capabilities.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0051	Corridors vertical separation	The separation method used for separation management shall be able to accept the vertical separation of the corridors.	<validated>	Depending on the corridor characteristics its vertical separation will change. The vertical separation of the corridors will serve as an input to establish separation in order to avoid conflicts between drones with different performances.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0052	Corridors lateral separation	The separation method used for separation management shall be able to accept the lateral separation of the corridors.	<in progress>	Depending on the corridor characteristics its lateral separation will change. The lateral separation of the corridors will serve as an input to establish separation in order to avoid conflicts between drones with different performances.	X	X	X					X			X		X		X									X	X	X

REQ-USEPE-D31-0053	Number of segments	The separation method used for separation management shall be able to accept the number of segments.	<validated>	In order to separate drones with different capabilities there will be different segments. The number of segments will serve as an input to establish separation in order to ensure that drones will fly in those that suit their capabilities.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0054	Segments' altitude	The separation method used for separation management shall be able to accept the segments' altitude.	<validated>	In order to separate drones with different capabilities there will be different segments. The segments' altitude will serve as an input to establish separation in order to ensure that drones will fly in those that suit their capabilities.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0055	Segments' maximum speed	The separation method used for separation management shall be able to accept the segments' maximum speed.	<validated>	In order to separate drones with different capabilities segments' maximum speed will change. The segments' maximum speed will serve as an input to establish separation in order to ensure that drones will fly in those that suit their capabilities.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0056	Segments' minimum speed	The separation method used for separation management shall be able to accept the segments' minimum speed.	<in progress>	In order to separate drones with different capabilities segments minimum speed will change. The segments' minimum speed will serve as an input to establish separation in order to ensure that drones will fly in those that suit their capabilities.	X	X	X					X			X		X		X									X	X	X

REQ-USEPE-D31-0057	Segments' heading	The separation method used for separation management shall be able to accept the segments' heading.	<validated>	In order to separate drones with different capabilities the segments heading will change. The segments' heading will serve as an input to establish separation in order to ensure that drones will fly in those that suit their capabilities.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0058	Segments vertical separation	The separation method used for separation management shall be able to accept the vertical separation of the segments.	<in progress>	Depending on the segment characteristics its vertical separation will change. The vertical separation of the segments will serve as an input to establish separation in order to avoid conflicts between drones with different performances.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0059	Segments lateral separation	The separation method used for separation management shall be able to accept the lateral separation of the segments.	<deleted>	Depending on the segment characteristics its lateral separation will change. The lateral separation of the segments will serve as an input to establish separation in order to avoid conflicts between drones with different performances.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0060	Tracking information	The separation method used for separation management shall be able to accept tracking information.	<validated>	Once drones are separated an instruction will be provided. The drone separation instruction will serve as an output to establish separation in order to avoid conflicts between users flying in the airspace.	X	X	X					X			X		X		X									X	X	X

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REQ-USEPE-D31-0061	Resulting airspace occupancy	The separation method used for separation management shall be able to provide the resulting airspace occupancy calculated after the conflict is solved.	<validated>	Once drones are separated the resulting airspace occupancy will be provided. The airspace occupancy will serve as an output to establish separation in order to know the number of users that can flight in a safe manner.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0062	Additional conflicts created	The separation method used for separation management shall be able to provide confirmation that no additional conflicts are created.	<in progress>	Once drones are separated the method shall have solved every additional conflict. The additional conflict avoidance will serve as an output to establish separation in order to solve all the issues and emergencies during a flight.	X	X	X					X			X		X		X									X	X	X
REQ-USEPE-D31-0063	Adapted airspace structure	The separation method used for separation management shall be able to provide the adapted airspace structure.	<validated>	Once drones are separated the method shall provide an adapted airspace structure where conflicts are solved. The airspace structure will serve as an output to establish separation in order to maintain the distance enough between all the airspace users and reduce the conflicts to a minimum.	X	X	X					X			X		X		X									X	X	X