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Abstract

The aim of this document is to define a Separation Management Process in the context of the U-space DCB process studied in DACUS Project. The document provides the definition of the scope of Separation Management, linking it to the DCB process. Through the definition of a set of Principles and assumptions, the process is contextualised. Finally, this deliverable defines a set of separation rules and responsibilities and a catalogue of applicable airspace structures, as well as the list of criteria for their application.

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Executive Summary

The aim of this document is to provide an approach to the offsetting of a Separation Management process within U-space, and in particular to highlight its link to the drone Demand and Capacity Balancing (DCB) process which is the core of DACUS project.

Separation Management defines the set of Separation Techniques (rules and responsibilities) associated with maintaining the separation minima, and defining the conditions of application of these techniques. An analysis has been done to identify the principles and assumptions necessary to define, in a theoretical level, this Separation Management process in U-space.

The Time Horizon in which Separation Management is foreseen has been defined as a framework for setting these principles and assumptions. The principles selected under which the Separation Management works are summarised under three main headings:

- *Full Automation of Ground U-space Services*, allowing a flexible range of automation levels for the Drone Operator systems
- *Simultaneous Operations under different Separation Schemes*, with co-existence of vehicles separated in a centralised way (by ground U-space services) and others separated in a decentralised way (self-separation) Therefore, separation responsibility is **set at mission level** for each individual drone operation;
- *Adaptive Application of Separation Schemes*, with performance being at the core of decision-making of the applicable scheme.

In fact, the proposed decision-making is laying on the values of a set of criteria. These are evaluated in order of priority for each mission, providing a key to navigate within a decision-tree scheme resulting in the selection of the applicable separation responsibility, the possible options moving between decentralized and centralized separation paradigms. This evaluation is done at least once at strategic level. When triggered by the DCB process, the Separation Management will also make use of the different airspace structures and responsibility assignments in order to increase the airspace capacity when needed.

From a Separation Management perspective, the airspace structures are the elements that provide procedural separation. Based on available literature and previous studies, three have been the structures considered for the airspace: 1) Non-structured; 2) Layers; and 3) Tubes. The question of which is the capacity turning point for the transition between each of the airspace structures considered is left for further research with the validation experiments in DACUS project.

1. Introduction

1.1 Purpose of the document

The purpose of this document is to develop a Separation Management process that fits into the DCB process designed in DACUS Project, providing a description of the set of Principles and Assumptions that will be applied to describe the separation management, as well as the responsibility roles that are going to be determined. The purpose of defining this set is to create a framework with some ground rules already determined.

1.2 Intended readership

Provided the content of the document, the first readership should be the partners of the DACUS project to feed the DCB process. Mainly the activities of Final Optimised drone DCB and Dynamic Separation Minima.

Nevertheless, it could be of special interest for all the different authorities in charge of establishing the future regulation for drone operations in urban environment by providing them with a global picture of this environment.

For the same reason, it may concern people in charge of drone operations development or people who will have to deal with drone operations: U-space service providers, local authorities at the level of city or region, operators, Air navigation Service Provider, just to name a few.

1.3 Background

This process definition is based not only in an extensive bibliography analysis, but also in the precedent work performed in DACUS deliverables D1.1 and D5.1, with which conclusions is aligned.

1.4 Structure of the document

For the definition of this process, a step by step approach has been followed. First, in Section 2 the Scope of the process and a reference to the Time Horizon envisioned to this process is described. This is helpful in order to explicit the concrete picture everyone has about the future, describing it with detail. Based on this, Section 3 presents the Principles in which this Separation Management process is based: the core principles that guide its development. And just after that, Section 4 states the assumptions needed to build the Separation Management process.

Section 5 describes how Separation Management process links to DCB. Section 6 describes a set of the Airspace Structures available as a tool to manage separation, and also the conditions applicable for their eligibility. After that, the separation management process is detailed in terms of the definition of

the set of criteria steering the choosing of the applicable separation scheme and the associated separation responsibility.

In this way, along the first section the building blocks of the Separation Management process are described and explained. And at the end the different separation schemes are explained, setting the framework of an algorithmic procedure able to be automated.

1.5 List of Acronyms and abbreviations

Acronym	Definition
ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependent Surveillance - Broadcast
AESA	Agencia Estatal de Seguridad Aérea (Spanish NAA)
AFIS	Aerodrome Flight Information Service
AGL	Above Ground Level
AMC	Acceptable Means of Compliance
AMSL	Above Medium Sea Level
AMULED	Air Mobility Urban - Large Experimentation Demonstrations
ANSP	Air Navigation Service Provider
ARC	Air Risk Class
ATC	Air Traffic Control
ATS	Air Traffic Services
ATM	Air Traffic Management
ATSP	Air Traffic Service Provider
ATZ	Air Traffic Zone
BRLOS	Beyond Radio Line Of Sight
BVLOS	Beyond Visual Line Of Sight
C2 link	Command & Control link
CARS	Common Altitude Reference System
CBD	Central Business Districts
CFR	Code of Federal Regulations
CIS	Common Information Service

Acronym	Definition
CISP	Common Information Service Provider
CNS	Communication Navigation and Surveillance
CONOPS	Concept of Operations
CORUS	Concept of Operation for EuRopean UTM Systems
CTR	Controlled Traffic Region
DAA	Detect And Avoid
DACUS	Demand And Capacity Optimisation in U-space
DCB	Demand and Capacity Balancing
DFS	Deutsche Flugsicherung GmbH
DO	Drone Operator
DSNA	Direction des Services de la Navigation Aérienne (french ANSP)
EASA	European Aviation Safety Agency
EATMA	European ATM Architecture
EVLOS	Extended Visual Line Of Sight
EU	European Union
FAA	Federal Aviation Administration
FAR	Federal Aviation Rules
FIS	Flight Information Service
FPV	First Person View
Ft	Feet
GM	Guidance Material
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRC	Ground Risk Class
GSM LTE 5G	Global System for Mobile Long Term Evolution 5G
HEMS	Helicopter Emergency Medical Services
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules

Acronym	Definition
ILS	Instruments Landing System
JARUS	Joint Authorities for Rulemaking of Unmanned Systems
KJ	Kilo Joules
LAANC	Low Altitude Authorization and Notification Capability
Lb	Libra
LBA	Luftfahrt-Bundesamt
LUC	Light UAS operator Certificate
Maas	Mobility As A Service
MTOM	Maximum Take-Off Mass
NASA	National Air and Space Administration
NM	Network Manager
NOTAM	NOTice To AirMen
NPRM	Notice of proposed rule-making
OSO	Operational Safety Objectives
PAV	Personal Air Vehicle
RLOS	Radio Line Of Sight
RP	Remote Pilot
RPAS	Remotely Piloted Aircraft System
RPS	Remote Pilot Station
RTK	Real-time kinematic
RTTA	Reasonable Time To Act
SAIL	Specific Assurance and Integrity Levels
SERA	Standardised European Rules of the Air
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SORA	Specific Operations Risk Assessment
STS	STandard Scenario
SUMP - UAM	Sustainable Urban Mobility Plan/Policy – Urban Air Mobility

Acronym	Definition
TLS	Target Level of Safety
TMPR	Tactical Mitigation Performance Requirement
TOLA	Take-off and Landing Areas
U1, U2, U3, U4	U-space service level
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
USSP	U-space Service Provider
UTM	UAS Traffic Management
V2V	Vehicle to Vehicle
VFR	Visual Flight Rules
VLL	Very Low Level
VLOS	Visual Line Of Sight
VMC	Visual Meteorological Conditions
VO	Visual Observer
WG	Working Group

Table 1: List of acronyms and abbreviations

2. Scope

2.1 Separation Management

In the DACUS project the **separation management** is delimited as the process of defining the set of Separation Techniques¹ (rules and responsibilities) associated with maintaining **separation minima** (see section 2.2), as well as of defining the conditions of application of the appropriate technique.

This process monitors the operational and environmental situation and compares the relevant parameters with the conditions of application of each Separation Technique. This comparison leads to a decision on the applicable Separation Scheme² (rules and responsibilities) during operations.

As a first approach to the definition of Separation Management, this deliverable D5.2 is only addressing the allocation of responsibilities. The definition of the rules that each potential **separator** would follow to assume this responsibility could vary at the level of each organisation (USSP, CISP, DOs) and is out of the scope of this task.

The **separator** is the entity (USSP for instance) or person (PIC or drone operator supervisor for instance) responsible for ensuring that the required separation minima between drones is not lost, so that to minimize the potential collision risk. The relevance of clearly defining the accountability of the role of separator at each moment in time is that the separator is the one liable for any damage resulting from a loss of separation linked to failed separation management.

A further remark is that while the separator is responsible for providing separation instructions, it is the PIC or the autonomous aircraft (Drone Operator/ manufacturer) the responsible for executing the instruction provided. This may imply that, in case of conflict, liabilities can also be held by the entity or person failing to execute the separation instruction provided. But establishment of liabilities is out of the scope of this task, so the focus of the Separation Management process will be solely on the definition of the separator role in each case, i.e. the person or entity managing separation and at least issuing separation instructions (also executing them in cases of PIC separation management or vehicle self-separation).

2.2 Dynamic Separation Minima

Separation Minima is the minimum distance to be maintained between two aircraft or an aircraft and a spatially defined zone of hazard so that the risk of collision is remote (maintain the risk of collision at an acceptable level of safety).

¹ Separation Technique: the set of rules and responsibilities available to manage separation.

² Separation Scheme: the sub-set of rules and responsibilities selected to manage separation in a given scenario.

Separation minima in a given airspace can be a fixed or a pair-wise value, the latter meaning that the value can be different between different pair of aircraft depending on their performance characteristics. Separation minima can also be dynamic, meaning that the value depends on the time of the day or even on the environment dynamic characteristics such as weather or status of CNS performances. This dynamic value gives the opportunity to react better on the demand or at certain temporal timeframe.

For Separation Management process, separation minima is an input. To go deeper into the detail of how to determine it, refer to DACUS D3.3 “Dynamic separation minima criteria” [10].

2.3 Time Horizon

An aspect that can introduce big changes in the set of potential separation schemes is the defined “time horizon” when these operations will occur. Time horizon expression does not necessarily mean to set a specific time in the future, but to establish some characteristics of the traffic, technological development, deployed U-space services and environment. The reference level of automation, both at service provision and at platforms levels, is particularly relevant for the Separation Management process.

The target horizon will be the time in the future when DCB process will be needed, i.e. when traffic demand due to the increase of drone business, will exceed the capacity of the airspace. At that moment in time DCB process will be needed to create a balance between the capacity and the operations demand. The proposed time horizon is expected to start when this happens.

One main reference for the time horizon associated to the level of technological and operational development of drone operations in Europe is the European ATM Master Plan [2]. The Master Plan, as the main planning tool for ATM modernisation across Europe, defines development and deployment priorities needed to deliver the Single European Sky ATM Research (SESAR) vision. Part of the vision is the integration of all aerial vehicles and the realisation of U-space as a framework designed to fast-track the development and deployment of a fully automated drone management system. The vision is being realised in four progressive and overlapping phases. The following figure is an extract of the phased approach in the ATM Master Plan focussed on the U-space aspects.

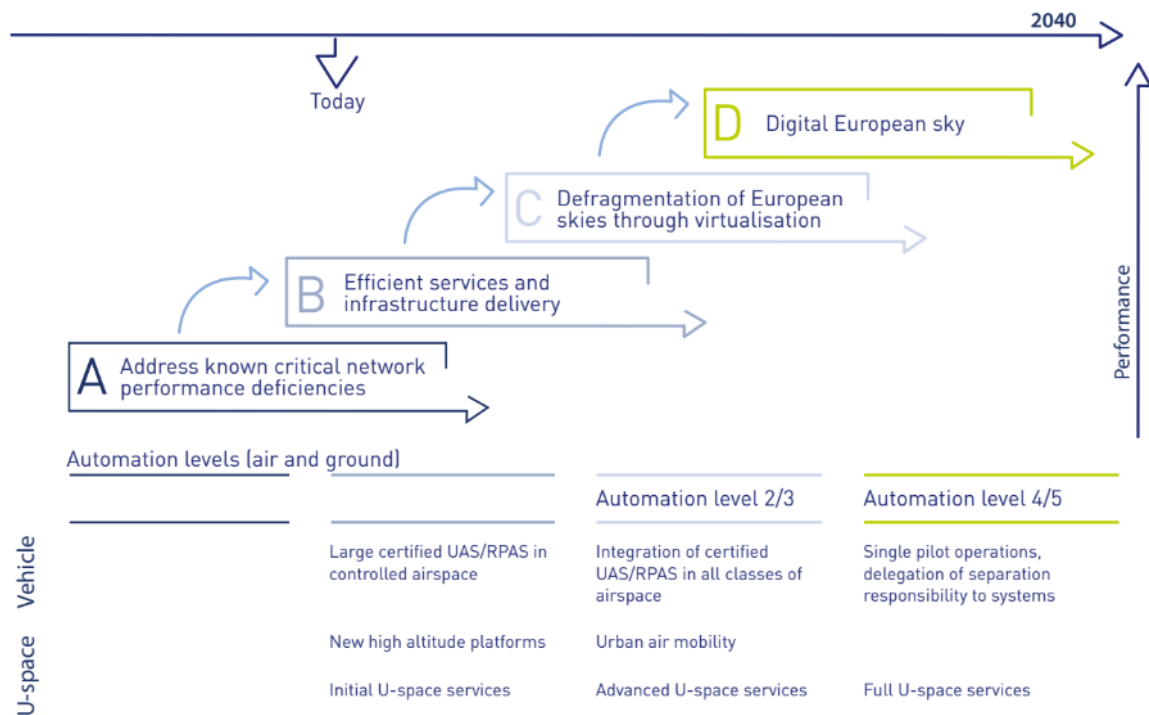


Figure 1: U-space phased approach within SESAR ATM Master Plan

According to the figure above, UAM will be deployed from phase C, together with the advanced U-space services such as Dynamic Capacity Management (at the core of DACUS DCB process [1]). From this time horizon onwards it can be assumed that DCB process will be needed. However, in DACUS, the target time horizon is set beyond that level, in a timeframe when it is also foreseen that the technological level allows for delegating the separation responsibility to systems. This corresponds in the referenced figure to the deployment of full U-space services and a level of automation 4/5 according to the scale set in the Master Plan.

FIGURE 4. LEVELS OF AUTOMATION

	Definition	Definition of level of automation per task				Automation level targets per MP phase (A,B,C,D)		
		Information acquisition and exchange	Information analysis	Decision and action selection	Action implementation	Autonomy	Air traffic control	U-space services
Action can only be initiated by human	LEVEL 0 LOW AUTOMATION	■	■	■	■	■	A	
	LEVEL 1 DECISION SUPPORT	■	■	■	■	■	B C	
	LEVEL 2 TASK EXECUTION SUPPORT	■	■	■	■	■		
Action can be initiated by automation	LEVEL 3 CONDITIONAL AUTOMATION	■	■	■	■	■	D	B C
	LEVEL 4 HIGH AUTOMATION	■	■	■	■	■		D
	LEVEL 5 FULL AUTOMATION	■	■	■	■	■		

Degree of automation support for each type of task

■ → ■ → ■ → ■

Figure 2: Levels of Automation in the ATC model of SESAR ATM Master Plan [2]

The scale above is based on the classic levels of automation taxonomy model used by human performance and safety experts in the SESAR programme, and mirrors the five-level model from the Society of Automotive Engineers (ranging from Level 0, ‘low automation’, to Level 5, ‘full automation’) [4].

According to this scale, the time horizon for DACUS will be ranging **from high to full automation**, with systems being able to initiate actions for most tasks and even to perform all functions under all conditions with no human operator in the loop.

Taking into account the expected technology that will be available in this period, the subsequent principles and assumptions are set in the following sections.

3. Principles

This section explains the principles that are going to be followed during the whole separation management scheme. They set the framework over which the process will be implemented.

Excluded from the principles are *degraded conditions*. In this context, the following definitions apply [7]:

- Nominal conditions: normal operations environment and system correctly operating, with all functionalities working with the expected performance;
- Non-nominal conditions: exceptional environment situations, such as a section of airspace closed. E.g.: declaration of an emergency area to be geo-fenced. All functionalities working with the expected performance;
- Degraded conditions: one or several system functionalities is lost or corrupted, not achieving the expected performance. E.g.: loss of C2 link.

3.1 Full Automation of Ground U-space Services

According to the time horizon set as reference for DACUS and the separation management process (see section 2.2), the reference automation level for the platforms and systems (including U-space services) is 4-5.

More in detail, **level 5 automation is set as reference for the ground U-space services** involved in the separation management. That means that the system is able to perform the assigned functionalities with no human operator involvement, even under *non-nominal conditions*. The rationale for this principle is that U-space is projected as a highly digitalized system able to capitalize automation (and even artificial intelligence) for the sake of a greater cost and operational efficiency. The independency from the human operator is seen as an opportunity to enable these efficiencies while ensuring flexibility and scalability to adapt to the dynamicity of drone operations, especially in urban environments.

The scope of the separation management process defined in the present deliverable are nominal and non-nominal conditions, leaving outside degraded conditions. Therefore, the principle of full automation for the ground U-space systems must be understood only for nominal and non-nominal conditions according to the statements at the beginning of section 3.

Finally, to allow some degree of freedom in the **side of the drone operator**, the minimum reference level of automation for that side operations and systems is level 4. That means that automation is a support to human operations in most tasks, non-excluding the human involvement. Automation level

5 is also considered, in the cases when drones are autonomous³ or automated under the control of ground systems. The consideration of a lower level of automation on the drone operator side is consistent with the results of the DACUS survey⁴. Based on the response of the drone operators and on available characterizations of automation level for UAS systems [8], the overview in Figure 3 has captured the automation levels per relevant mission type. The figure shows that currently, although missions from the transport type already show a high level of automation and can address complex BVLOS operations, others from the inspection type still rely heavily on the pilot involvement and very likely might continue to require the pilot due to the nature of the mission. The complete survey results in this regard is included in the Appendix A.

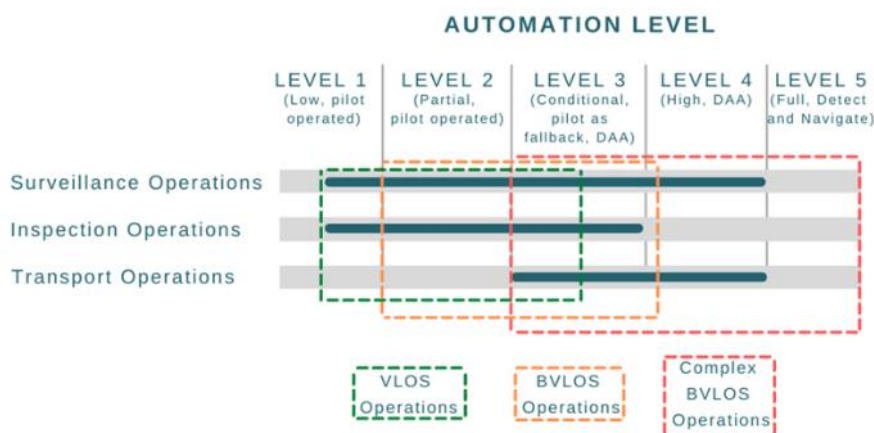


Figure 3: Distribution of automation levels per mission type, as of today.

3.2 Simultaneous Operations under Different Separation Schemes

It is considered possible the co-existence of centralised separation instructions with self-separation in the same airspace, i.e. allowing self-separation even in airspace with provision of U-space services. The mission definition is what drives the scheme to follow. Therefore, in an area of airspace can occur simultaneous operations under different schemes: some vehicles self-separating, with ground traffic information provided, while others being separated by U-space service.

An example of this would be:

³ See section 3.2.2 for a definition of autonomous vehicles.

⁴ Here, several drone operators characterized the level of automation based on the operation mode (VLOS, BVLOS) and DAA capabilities. Additionally, they specified if their operation is required to be pilot operated. Although this survey did not have a wide respondent participation (16 responses), it only considered operations being performed on a regular basis and with a high potential in the future (food delivery, emergency services, infrastructure inspection). It also addressed all mission types considered in DACUS (inspection, surveillance and transport type).

- A drone performing infrastructure inspection piloted from the ground which separation responsibility is on the PIC (who is responsible for ensuring that the drone is within a certain area close to the building),
- surrounded by traffic separated by ground U-space service, so that service provides separation instructions to:
 - ✓ Remote PIC **OR**
 - ✓ Highly automated Drone Operator's system **OR**
 - ✓ Highly automated drone so that instructions are followed automatically by the on board system.

The potential set of options allowed can depend on the area (only certain areas allow self-separation but others don't), time of the day and other static considerations. In addition to this, dynamic considerations apply at operation/ mission level for the selection of each individual scheme (as it is developed in section 7).

For the performance of drone traffic management in a given airspace it is considered the need for ensuring a *common situational awareness* for all the operating traffic in the area. The EASA U-space regulation [6] establishes the requirement of provision of a **traffic information service** containing information on any other conspicuous air traffic, which may be in proximity to the position or intended route of a UAS flight. This traffic information can be considered as the *enabler* for the performance of the Separation Management process, gathering all the information necessary to perform appropriate separation actions within each portion of airspace. This enabler serves both for ensuring situational awareness of ground U-space services when performing centralised Separation Management (see next section 3.2.1) and of Drone Operator's roles in the case of decentralised approach (see next section 3.2.2).

3.2.1 Centralised Separation Responsibility Description

Centralised separation responsibility means that all traffic managed by a given service provider is separated by it, in opposition to the situation in which there are several entities managing separation in a de-centralised way, being those UAS operators, PICs and even autonomous⁵ vehicles. It could be therefore the case that various U-space service providers manage each one its own traffic in a shared airspace and it is still applicable talking about centralised separation management if all separation responsibilities rely on the U-space ground services.

In DACUS the principle sets further that **there can be more than one USSP in each airspace**, and so the separator role in the Centralised Separation Management Process **is not a unique central process** in each U-space airspace. In this sense DACUS is architecture agnostic, being possible to account both for one unique central entity in a monolithic architecture or for a federated approach with various USSPs interplaying in the same airspace.

⁵ See section 3.2.2 for a definition of autonomous vehicles.

3.2.2 Decentralised Separation Responsibility Description

The principle applicable in the context of Separation Management in DACUS is that separation responsibility can be handled not only in a centralised manner (as described in the previous section) but also by diverse entities or persons sharing the same airspace. This leads to situations in which *the separator can be the PIC, the Drone Operator or even the drone itself* (these latter in case of fully autonomous flights being self-separated).

It is relevant here to clarify the difference between highly automated flights and autonomous flights applied in the context of this document [5]:

- **Automated** flight is the one that is linked to a system able to control the vehicle, such as autopilot or cruise control, and minimizing human inputs.
- **Autonomous** flight is the one with a system that is not only able to control the vehicle but also to respond to unexpected hazards.

The definition from ICAO [11] of **autonomous aircraft** is “*an unmanned aircraft that does not allow pilot intervention in the management of the flight*”.

3.2.3 Ground U-space Separation Management

Within DACUS, it is adopted that the decision of the applicable separation scheme is always done by the ground U-space system (either CISP or USSP since the project is architecture agnostic).

However, it is recognised the possibility that other decision-making schemes are adopted, linked to the **governance model** of the U-space system in each area of deployment. In fact, the governance model will determine how each actor/ role is involved in decision-making, including the regulator, city managers, DOs, etc. Two particular possibilities that are considered are:

- Collaborative Decision Making schemes in which decisions are reached via consensus between the relevant stakeholders if time allows it;
- Collaborative working schemes, in which the decision-making role can interact with other role(s) to act upon the values of the decision parameters. An example would be two USSPs working in the same area but providing different services to the same drone, where the USSP providing the separation-related services can ask the other USSP a certain level of service so as the separation management can be performed in the required way.

3.3 Adaptive Application of Separation Schemes

As stated in the previous principle, different separation schemes will be applied in the same airspace according to a catalogue of available schemes suitable for a given airspace volume. For each individual operation/ mission the separation scheme can also evolve along time to meet the demand and capacity pictures at each time.

Pivoting the separation responsibility between centralized (ground U-space services) and decentralized (Drone Operator system or vehicle level either PIC or autonomous drone) is done according to the values of a **set of criteria** defined in Section 7.

In terms of safety:

Centralisation is assumed to be safer since the same system in charge of common situational awareness is the issuer of separation instructions.

The drawback is the latency due to the load of data to be processed, which has to be compensated with other mitigations, such as the level of automation of UAS.

In addition, the safety level provided by centralised responsibility with regard to decentralised option varies with diverse factors: for instance in the proximity of vertiports, where high traffic densities are expected and routes are converging to a limited number of points, centralised responsibility could be a must. Here below is an example of a potential trade-off between the level of centralisation in separation management and the UAS automation level for different levels of risk (either collision or ground risk).

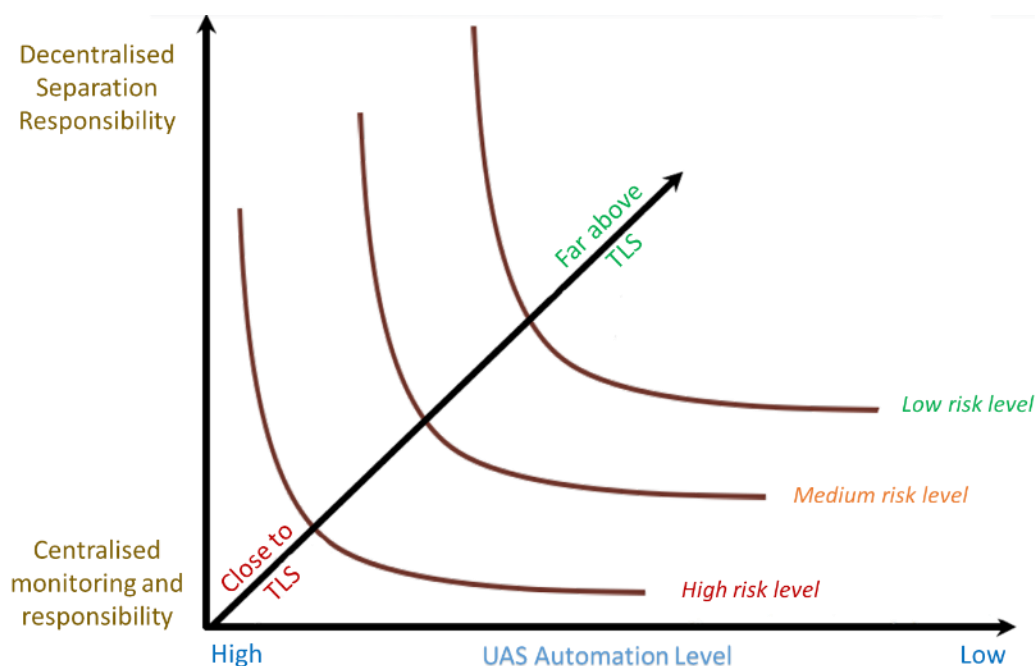


Figure 4: Principle of trade-off between level of risk – centralisation – automation

In the graphic above it can be seen, for a given risk level, how centralized separation responsibility and UAS automation level are balanced to maintain the safety level:

- When the operational picture is of low risk (curve farthest from the axis origin) even low automation of UAS allows for a medium-high level of decentralisation. With medium automation level of UAS it is assumed that all traffic can be self-separated;
- On the other side of the graphic, high risk level (close to the axis origin and thus to the Target Level of Safety [1]), only the highest level of UAS automation allows self-separation, whereas centralised separation management is the safety enabler when the UAS automation level is low.

Beyond being an input for the setting of separation responsibility, automation also provides the opportunity of developing more complex and dynamic decision trees for setting separation minima. A highly automated ground U-space service can calculate in real-time the optimum pair-wise separation minima and communicate it to autonomous drones able to process the information and to incorporate it to their own autopilot algorithms also in real-time.

3.3.1 Performance-based Separation Decision-Making

The decision-making for the application of separation scheme at mission level will take into account the performance of the drone as well as the level of CNS performance provided in the area of operation. Other aspects related to the airspace and traffic characteristics will also impact the decision on the separation scheme for the drones to be able to maintain an adequate separation.

The set of applicable criteria is listed and defined in section 7. The approach for the selection is to rank these criteria so as the decision-making process evaluates each of them in order, according to the ranking.

4. Assumptions

The following are the assumptions considered in this process definition, grouped in four conceptual categories:

A) Separation Scheme:

- The reference for separation (either based on time or on distance) is assumed to be solved. The Separation Management process will not consider any discussion on this topic.
- It is assumed that the adaptive application of separation schemes along time is smooth and will not pose safety concerns to the airspace users. For instance, the change of airspace structure along time doesn't create any issue in the transitory stage.
- Airspace structures allow to increase capacity in prejudice of flexibility and flight efficiency.
- Centralised separation management is safer than the decentralised approach where each vehicle is self-separated, and therefore more suitable for situations when risk level is close to the Target Level of Safety (high risk).

B) Vehicle:

- Vehicles may have different characteristics (large, small) and different performance capabilities (operating range, preferred flight levels, nominal cruise speeds, etc.).
- To enable that the U-space services involved in the separation process operate in fully automated mode, certain technological assumptions have to be made. In particular regarding drone capabilities this implies at least:

- i. Position reporting: Capability that allows the drone to communicate its position to traffic management services (U-space services).

Besides, automated drones and drones operating in the certified categories are assumed to have:

- i. DAA (Detect and Avoid): Capabilities that allow the drone to detect and avoid collisions with other vehicles and other obstacles;
- ii. V2X: Capability that allows multiple drones to communicate with each other and with infrastructures (for instance in the framework of Internet of Things).

C) Operational:

- In line with DACUS D1.1 [1] Section 11, the majority of drones will be autonomous and flying BVLOS operations. And those in VLOS operations, will be assumed to be geo-caged.
- Free route is allowed whenever possible: no restrictions should be imposed on the path of the drone.
- Only the cruise trajectory part is considered in the Separation Management Process.
- Manned aviation (e.g. general aviation) is out of scope of the Separation Management Process defined in this deliverable in the sense that the document does not address how the responsibility for manned aviation to tackle with separation from drones and

other obstacles. It must be clarified that this deliverable, as part of the definition of the allocation of separation responsibility for drones, does address the separation of drones from manned aviation.

- The CARS issue is assumed to be solved.

D) Traffic Management and U-space services:

- The following service functionalities are automated: traffic information integration, conformance monitoring, warning and instructions emission.
- Communication performance is compatible with the level of service required for autonomous operations and full automation of U-space services (in particular link availability and latency nominal performance).
- The position of every drone is assumed to be known, either via collaborative or non-collaborative systems.

5. Separation Management link to DCB

5.1 Overview of Separation Management within DCB

The U-space DCB process spans over various time frames from long-term planning to post-operations. Processes and measures at each frame are decided upon the analysis of a rolling demand and capacity picture increasing in accuracy up to the day/ time of operations (tactical phase). The figure below represents the U-space services and main processes involved in U-space DCB [1].

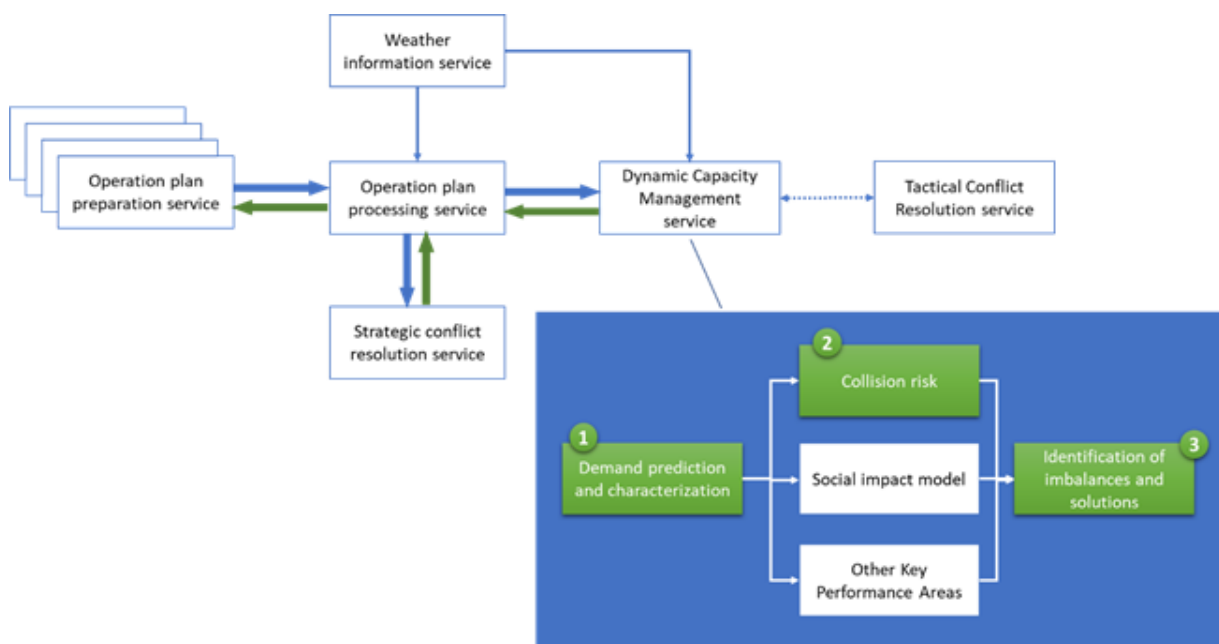


Figure 5: U-space services and main processes involved in drones DCB

Within the blue box are the main internal processes of the dynamic capacity management service, that lead to the identification of demand and capacity imbalances and the selection of solutions. Highlighted in green is finally the particular path that is relevant for separation management in terms of identification of applicable separation scheme:

1. Depending on the phase, the **demand picture** for a given airspace can be quite **uncertain** according to the diversity of operations expected: operation plans for last-mile delivery will only be available on short notice, whereas recurrent operations can be anticipated with less uncertainty.

Capacity has also associated a **level of uncertainty** linked, for instance, to weather forecast or to other factors related to the ground risk such as population density forecast.

2. The **safety impact** (ground and air risk linked to the *risk of collision*) for the day of operation is calculated using as inputs the available demand and capacity data and the applicable **separation minima framework** (see section 2.2). This safety indicator has associated the inherited uncertainty of the input data.
3. In case the calculated safety impact is above the **Target Level of Safety (TLS)**⁶, there is a safety hotspot for the time and airspace of operation under analysis. This hotspot has to be solved through the application of pre-defined DCB measures.

*One possible measure to solve a safety hotspot is a change in the **applicable separation scheme** able to provide increased capacity.*

Figure 6 below depicts in more detail the link between Separation Management and drone DCB by providing a closer look to the 1-2-3 processes described above. These processes are performed iteratively until either the hotspots are solved or the time to operation is closer than the **Reasonable Time To Act (RTTA)**⁷. In that case, the concerned operations that enter can be subject to more severe demand measures allowing in one-step to reach TLS.

It must be noted that the hotspots can also be linked to the social impact of the planned traffic picture. These type of hotspots are not so explicitly depicted in Figure 6 since they are not solved through the application of DCB measures linked to Separation Management.

⁶ TLS is the collision risk level (combination of severity and probability of collision risk) in a given airspace above which the planned operational picture cannot be considered safe. This risk level linked to the pair-wise collision risk in a given airspace can be defined in multiple ways, addressing, for instance thresholds for: the instantaneous average collision risk, the instantaneous maximum collision risk between any two aircraft, the maximum collision risk between any two aircraft over a defined period, the maximum percentage of aircraft over instantaneous maximum collision-risk, etc.

⁷ For any drone operation, there is a time period far enough before flight that a disturbance to the operation has minor repercussions. After that time the effect of change becomes harder to accept. This time is known as the “reasonable time to act” (RTTA) and can be different for different operation types.

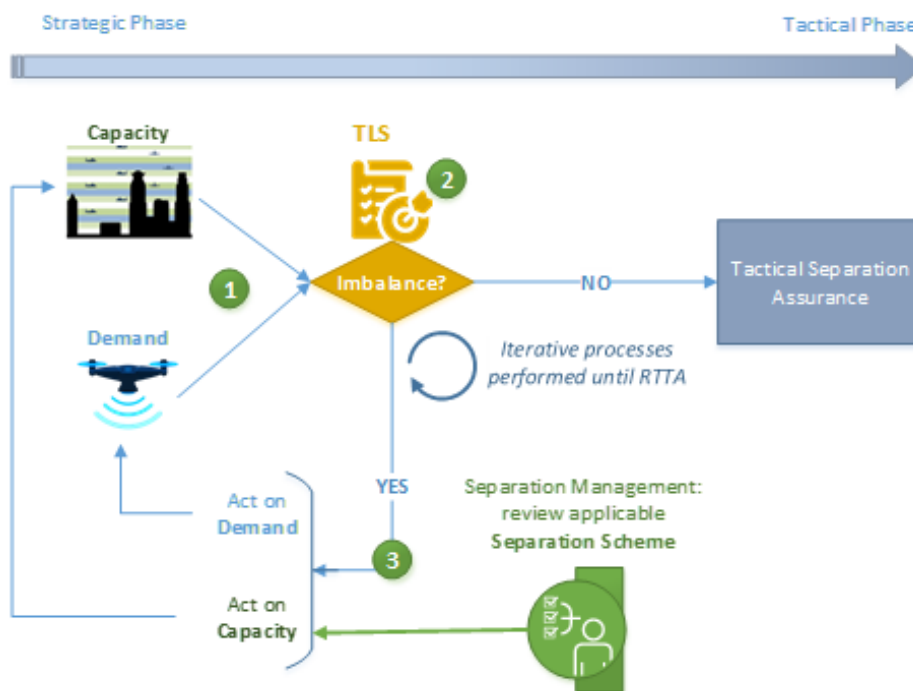


Figure 6: Separation Management within drone DCB Dynamic Capacity Management

The following sections provide details about the specific separation schemes that are relevant for the catalogue of DCB measures at each time frame, and therefore must be understood as instances of Separation Management in the context of DCB, i.e. when the process is triggered by an imbalance as depicted in Figure 6

5.2 Strategic Phase

Strategic phase is the time frame with the higher uncertainty within drone DCB process. Therefore, DCB measures which have higher stability under demand changes will be prioritized in this phase. The type of measures under Separation Management category of this nature are related to the implementation of airspace configurations and structures that provide **procedural separation** for the expected traffic. Examples are:

- **Layers of airspace** splitting traffic according to navigation performance.
- Deployment of **fixed airways** statically de-conflicted for the management of traffic flows.

5.3 Pre-tactical Phase

In the pre-tactical phase, there is more confinable information about the planned operations and weather forecasts. Uncertainty still can play a role due to:

- New airspace reservations/ geo-fences.

- Pop-up non-recurrent event impacting ground risk or social impact.

In this phase, the same type of separation management measures already mentioned for strategic phase are also applicable. For less severe imbalances, separation management DCB measures are in the form of restrictions to the responsibility in separation management:

- Separation management by Pilot in Command, not being allowed vehicle fully automated self-separation;
- DO ground separation responsibility;
- **Centralised separation** management, performed by U-space ground services.

5.4 Tactical Phase

This phase takes place during the execution of the operations and includes monitoring the overall traffic picture. In case there are disturbances leading to the generation of safety hotspots, separation management DCB measures can be deployed as far as time to deploy them is fast enough so that solution arrives on time to solve hotspot before the situation is not admissible from a safety point of view.

The type of separation management DCB measures applicable in the tactical phase are in line with those already described for the pre-tactical phase: i.e. changes in the applicable separation scheme restricting the level of separation automation and the responsibility in separation management.

5.5 Non DCB Triggered Separation Management

It must be highlighted that Separation Management process also acts independently from DCB. A Separation Scheme shall always be selected even in situations when no imbalance has been detected or foreseen.

In fact, the operational reference is a situation where Separation Management **acts at strategic level**, building on the most probable values for the criteria considered as decision factors in setting the applicable separation scheme for the day of operations. Although there will be high uncertainty in certain aspects, this will mainly impact the final selection of the applicable **separation minima**, having less relevance for the allocation of the separation responsibility.

From that point onwards in the traffic management process, Separation Management will only be triggered if needed by DCB in support of increasing capacity. In that case, the trigger will be related to a DCB imbalance, and therefore to a risk above the TLS, which at its turn will be due to a significant change in one or many of the capacity and/or demand influence factors [1]. Since some of these factors are also criteria for the selection of the applicable separation scheme (see section 7), the Separation Management process launch as DCB measure will also result in changes in the applicable separation scheme so that capacity can be adapted to the demand and risk can be decreased.

6. Airspace structures

DCB process is expected to take place when demand is high enough and needs to be managed. Therefore, to ensure that aircraft operate safely, as part of the separation process, airspace structures can play an important role. It is essential to define airspace structures that can accommodate different demands while maintaining a certain level of safety, providing therefore procedural separation which minimises the tactical separation needs. In “D 5.1 Structures and Rules in Capacity Constrained (urban) Environments” [14], different airspace structures were presented after a bibliography review. In this document, some of these airspace structures are proposed:

- **Non-structured:** In this structure design, all drones can use the airspace freely, without any non-physical constraints. This design allows a direct routing in drone operations. However, in order to ensure safety, tactical separation assurance needs to be in place for the drones to avoid each other while flying their optimal route. With regard to the representative operations introduced in the next section (operations of surveillance, inspection and transport type), this structure concept might seem suitable for all operations types as it offers maximum flexibility to accommodate the operational characteristics of the three types.
- **Layers:** In this design, the airspace is segmented into layers of certain vertical dimensions. In each layer specific traffic mechanisms can be applied, such as traffic flows limited in the heading range or to assign layers only for de-confliction purposes. This structure design also provides the possibility to accommodate drones equipped with different performance characteristics. Here it might be necessary to implement dedicated tubes or cones above take-off and landing sites for the vehicles to enter the layers.
- **Tubes [13]:** As a maximum structuring of airspace, four-dimensional tubes provide a fixed route structure in the air. The aim of this structure is to increase predictability of traffic flows by means of pre-planned conflict free routes. The nodes of the graph are connection points for one or more routes. The edges are the tubes connecting two nodes. Tubes at the same horizontal level never intersect, except at the nodes, and are dimensioned to fit one aircraft in the vertical and horizontal plane. A lateral offset is used between layers to allow for smooth climb and descent paths. As a result, aircraft are only allowed to climb through one layer at a time.

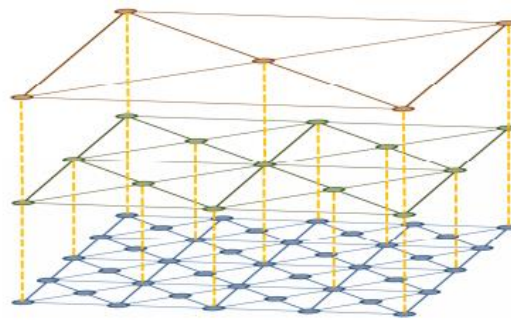


Figure 7. An example tube topology with three layers of decreasing granularity. The dashed yellow lines are used to indicate the placement of nodes above each other. Tubes are bi-directional [13]

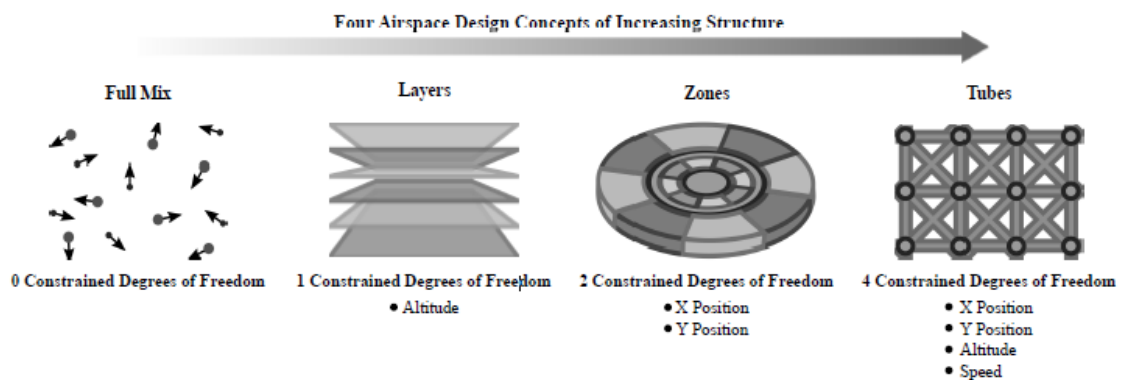


Figure 8. Four point airspace structuring framework. The level of structure is increased from Full Mix to Tubes by incrementally increasing [15]

With regard to airspace structures and capacity, the objective of DACUS Task 5.3 is to define airspace structures that allows different demand levels. It is worth wondering which airspace structure is the most suitable for each scenario. Metropolis project [13] made an analysis focusing on answering two question:

- 1) Which airspace concept is most suitable for an urban air transportation system under extreme traffic densities?
- 2) Does adding more structure to the airspace design increase the maximum capacity of the airspace?

It can be expected that a more structured airspace will imply a higher level of safety. However, this is not always true.

The following main conclusions can be drawn from the Metropolis Project [13]:

- **Capacity is maximized when vertical constraints are used to separate traffic with different travel directions at different flight levels as for the Layers concept.** This mode of structuring

improved performance over a completely unstructured airspace by **decreasing relative velocities between aircraft cruising at the same altitude**, while allowing direct horizontal routes. The reduced relative velocities also increased the stability of the airspace to tactical conflict resolutions.

- Conversely, structuring modes that imposed horizontal constraints, such as the Zones and Tubes concepts, caused a convergence of traffic at the inter-sections of structural elements. These traffic concentrations reduced overall performance for such concepts.
- **The optimum method of structuring was found to be independent of density. Capacity generally benefited from a reduction of structural constraints, and no reversal for this trend was found for the scenarios simulated.**
- While the segmentation into aircraft with similar headings, as seen in the Layers concept, still shows a beneficial effect when compared to the unstructured case, the strict structuring as employed in **the Zones and Tubes concepts only reduces performance without any gains in safety, nor any other metric**. For the traffic densities simulated in the current study, no reversal can be observed for this trend.
- **For both nominal and non-nominal experiments, the Layers concept was found to be the best balance between organizational, operational and environmental metrics.**
- In terms of safety, the number of conflicts and intrusions increased proportionally with traffic density, even for the Tubes concept, where conflict-free trajectories should have been pre-planned. **A possible reason for this is that the uncertainty margins were inadequate.**

Based on Metropolis results, **layers concept** seems to be the most suitable airspace structure to find a compromise solution between capacity, operational efficiency and safety.

In “Metrics to characterize dense airspace traffic” from Altiscope [12], one of the conclusions obtained from the results is that for a given number of aircraft in flight, the greater the number of aircraft on similar headings the higher the density that can be managed. Therefore, it is aligned with the results of Metropolis project.

On the other hand, the airspace structure will not only depend on the demand itself but the percentage of each type of missions. Tubes or fixed routes could be a good approach for deliveries with fixed departing and arriving points. However, they are not a good solution for other business cases since aircraft sometimes must fly longer routes than required or wait if the route is congested.

Taking into account all described above, DACUS will consider non structured airspace as the general concept, introducing layered structures when the demand is close to reach the maximum capacity for non-structured airspace. Additionally, tubes can be considered as necessary in environments with a high level of constraints, as defined in section 6 of DACUS D5.1 [14].

As it is seen above, the introduction of airspace structures can help to increase capacity. However, determining at what point of demand these structures should be introduced is essential but not easy. The outputs from DACUS WP4 will be used as an input to the discussion. One of the experiments to be carried out in this work package will consist of simulating different airspace structures to determine from which point free flight is not admissible (for safety reasons) and how structures can introduce improvements in safety.

7. Separation Responsibility

7.1 General Context

As stated in the principles (section 3), the separation management process envisaged will be at operation/mission level and dynamic to adapt to the demand and the airspace capacity to create a routing environment as “free” as possible. The starting point is an airspace in which the free route is applied, until due to the need of balancing the demand and the airspace capacity some constraints need to be introduced.

According to this framework, the proposed approach consists on defining a set of criteria whose status or value will determine the level of centralisation of the separation management and the level of routing freedom that can be given to the vehicles.

Depending on the situation (set of values for the defined criteria), the Separation Management process will produce an applicable **separation scheme**, setting how the separation is implemented in terms of responsibility and applicable process. The following figure summarises the possible separation schemes considered in the framework of DACUS (according to the chosen time horizon and the related principles stating no human intervention on the ground service provision side).

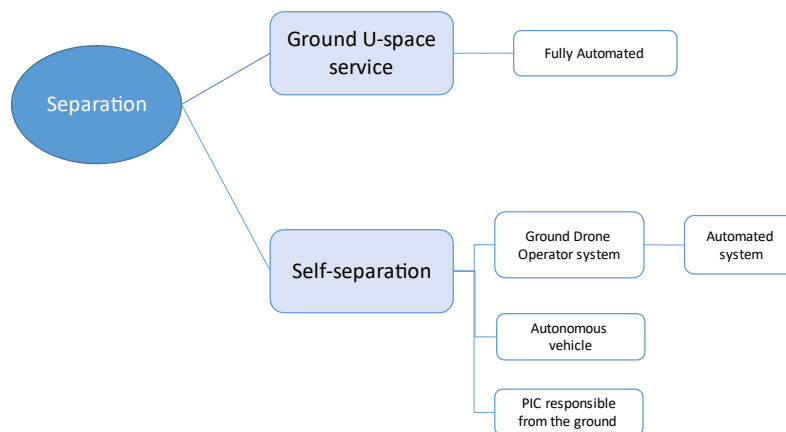


Figure 9: Options for Separation Management Scheme

First, there is a differentiation if the service is provided by a ground U-space service, or if instead there is self-separation.

In case separation management service is provided by a ground U-space service, this is assumed to be completely automated (see section 3.1).

On the other hand, when considering that the Drone Operator will be responsible for the separation, three other possibilities are presented:

- The Ground Drone Operator system monitors all its drone fleet and issue instructions to the drones to make sure that the traffic development is safe. This option is considered to be performed by an automated system.
- The vehicle is responsible of maintaining a safety separation with other vehicles. This is applicable to autonomous vehicles. These vehicles are assumed to be equipped with DAA technology (see section 4).
- The Pilot in Command (PIC) is responsible for the separation management from the ground.

In these three cases, situational awareness of surrounding traffic and obstacles is an enabler for the safety of all operations. To allow ground U-space services building the common traffic picture, also all drones provide during the whole flight information about the position of the drone. Further to common situational awareness, it is acknowledged that there is a clear interplay between conflict prediction and detection and separation management, so that the later might relies on the former to identify potential losses of separation, although it is not in the scope of the present task to dive into this operational link.

It must be highlighted that, according to the principle of simultaneous operations under different separation schemes (section 3.2.1), the separation scheme is applicable at the level of operation, being possible that different separation schemes are shared in a common airspace.

7.2 Criteria

This section describes some potential mission-related criteria that could be used to decide on the optimum separation scheme. The list initially considered is:

- Type of vehicle & equipment;
- Type of flight;
- Number of operations in the area;
- Degree of airspace structure;
- Traffic organization (segregated/ integrated);
- Type of area;
- CNS performances;
- Weather.

Although it is not included as a decision criteria, it should be noted the importance of the mission type since this will determine among other things the type of vehicle that will be used and the type of flight that will be performed. These are some of the considered missions:

- | | | |
|---|---|--|
| <ul style="list-style-type: none"> • Inspection • Seed sowing • Firefighting | } | <p>There is a PIC who controls the drone and can be the responsible for the separation. In addition, these missions usually are VLOS or EVLOS.</p> |
|---|---|--|

- Delivery
- Surveillance
- Vehicle (transport)
- Emergency
- Photo activity
- Film making
- Recreational activity
- Runway inspection
- ILS measurement

The air traffic controller will be usually the one who oversees the separation as with airplanes.

The following subsections discuss each one of the defined criteria and the relation of its possible statuses or values with the selection of an applicable separation scheme.

In parallel with the development of this deliverable a survey has been conducted internally within DACUS project. The structure and results of the survey are included in Appendix B Survey on Separation Decision Criteria. It must be highlighted that since the survey was launched in parallel with the deliverable the list of criteria considered in the former is not 100% coincident with the list finally included in the later. Some criteria have been re-formulated conceptually and one of them has been finally discarded in the final list included in this deliverable. It is the case of the “Population Density”, which is a dynamic parameter implicitly included in the level of risk for a given area, which is already the trigger of the Separation Management process by DCB (see section 5).

7.2.1 Type of Vehicle & Equipment

First, there is a differentiation between unmanned drones and manned drones. Unmanned drone: The size of the vehicle will be important because of the equipment it can have (small drones won't have same equipment than the big ones, not in quality and number). In addition, the impact if a failure occurs is different for the small ones than for the big ones.

- Small: Depending on the equipment the separation can be provided by ground U-space service or the Drone Operator system (if avionics allow it) or by the PIC. For example surveillance and inspection type missions will use small drones because they do not require to carry heavy payload [1].
- Medium: The impact of the failure of this kind of UAS is bigger than the previous ones. In addition, due to the increase of the size, the equipment of the drone can be improved and more and different tools can be included to support the self-separation.
- Large: The large ones are the ones that biggest impact will cause in case of accident. Because of safety risk, autonomous self-separation is excluded for this category to avoid great damages. In the case of being a manned drone, as there is a pilot inside the vehicle, this pilot could be the one in charge of the separation although given the high risk, U-space

ground service should closely monitor that the safety of these vehicles is inside acceptable values in every moment.

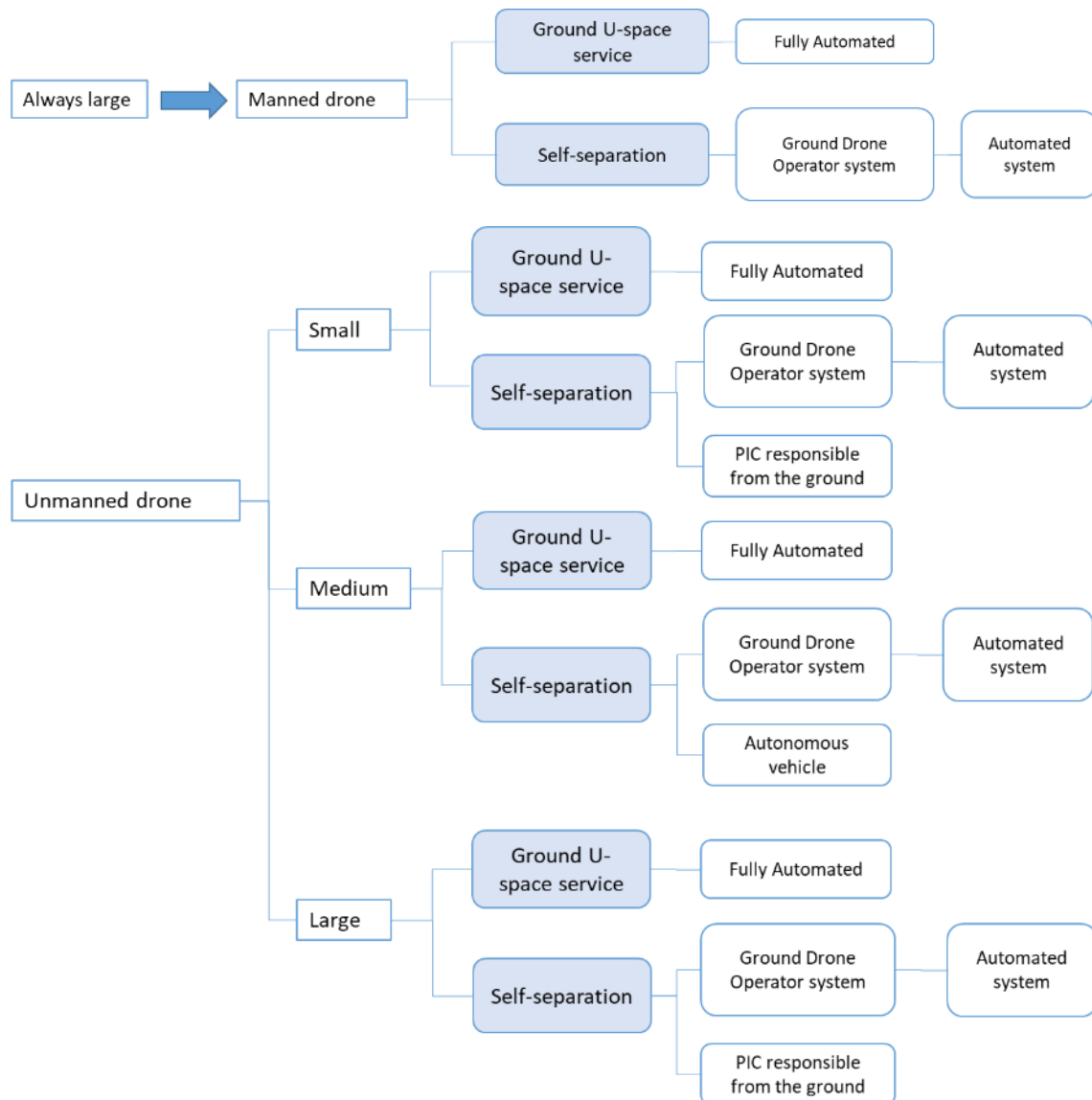


Figure 10. Criterion of Type of Vehicle and possible Separation Schemes

7.2.2 Type of flight

At the early stages of the development of the operational framework for drones, three main flight modes were considered as being the most representative of the way the remote pilot/ control interacts with the drone:

- VLOS (Visual Line Of Sight): They are the most common RPA and they have to be always at sight of the pilot, so this one can take the responsibility of the separation with the other drones around. When this flights occur in non-segregated way and coexist with other type of traffic it is important that there is always situational awareness of surrounding traffic by the PIC by electronic means, and not just visual piloting, to maintain the TLS. This is specially relevant in urban congested environments
- EVLOS (Extended Visual Line Of Sight): These operations require the support of an Unmanned Aircraft Observer⁸ for the observation and control of the drone so that between both of them the separation can be managed.
- BVLOS (Beyond Visual Line Of Sight): There is no visual sight of the operation so all possibilities are available, except the one of autonomous drone since this type of flight is referred to the external piloting of the drone (usually by a PIC). So either the drone is supervised by ground U-space services or the PIC/ DO is the responsible for the self-separation.

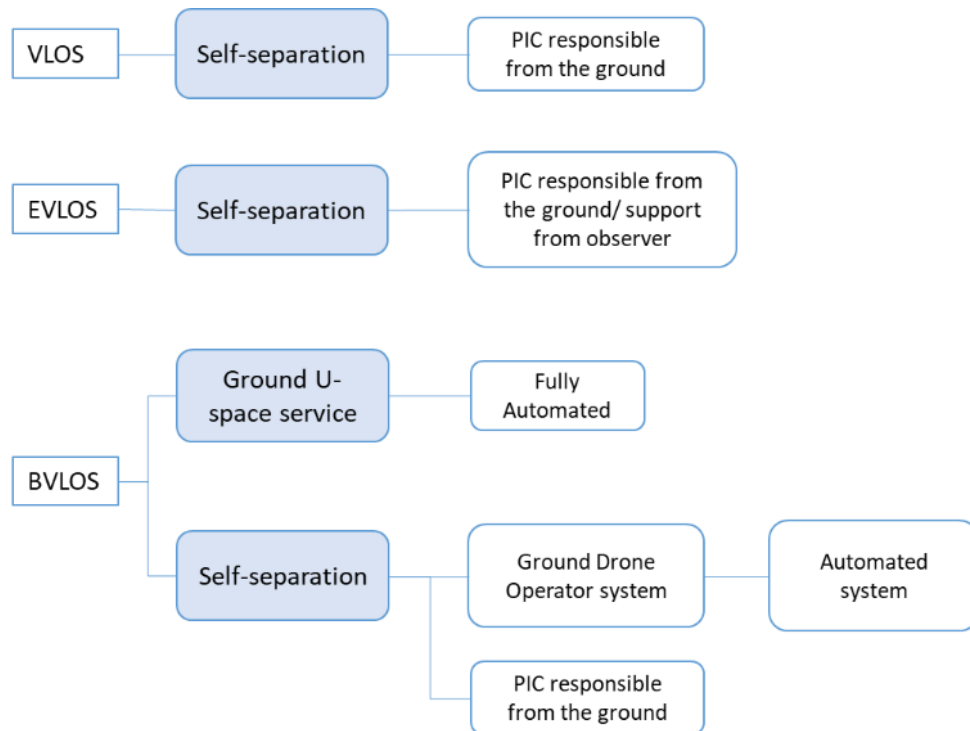


Figure 11. Type of flight criterion.

⁸ According to [16], an Unmanned Aircraft Observer is “a person, positioned alongside the remote pilot, who, by unaided visual observation of the unmanned aircraft, assists the remote pilot in keeping the unmanned aircraft in VLOS and safely conducting the flight”.

At the target time horizon set for this deliverable, the types of flights used in the previous classification are, in the least, not comprehensive enough for covering all possible operations and they may even be outclassed. To ensure comprehensiveness of the “type of flight” criterion, it must be coupled with the level of automation of the vehicle. The classification proposed for this level of automation is the one referenced in Figure 2. Therefore, the BVLOS tree is also applicable for highly automated vehicles (level 4), whereas autonomous vehicles will be categorised beyond BVLOS with the separation responsibility usually assigned to the vehicle itself.

7.2.3 Number of Operations in the Area

The number of operations within the airspace in which the operation takes place is another decision factor where the acceptable values depend on the capacity of that specific space. That is why the possibilities will be divided in three options: low, medium, and high number of operations:

- **Low:** If the number of operations is considered low, vehicle self-separation could be allowed because it would be acceptable the self-separation management to maintain the safety levels.
- **Medium:** If the number of operations increases both central/ground U-space service and self-separation could be applicable.
- **High:** When the number of operations is considered high and due to the increase of the complexity of controlling the airspace, a ground U-space service will be responsible for the separation management.

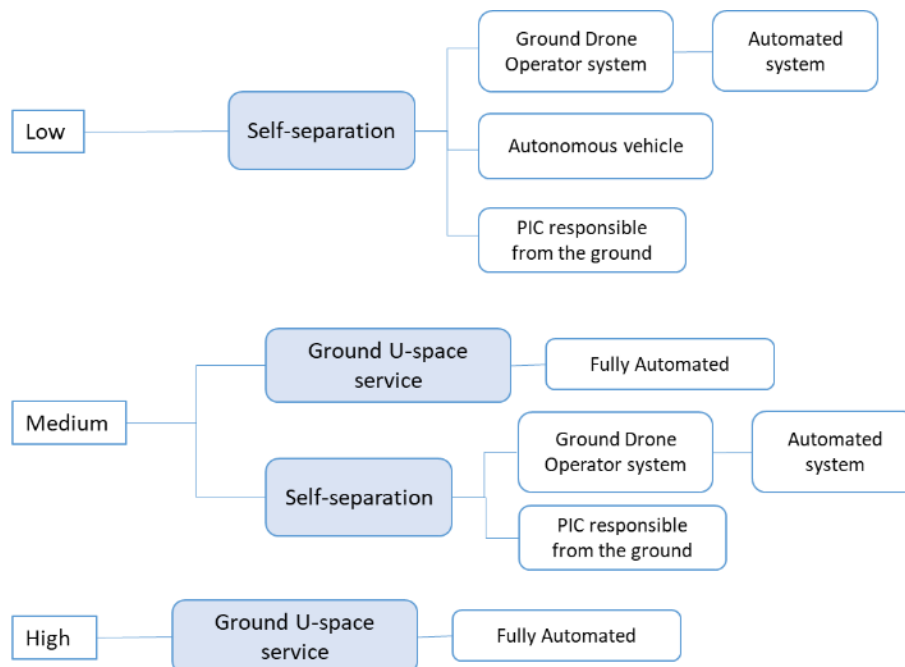


Figure 12. Number of Operations criterion.

7.2.4 Degree of Airspace Structure

A non-structured area is assumed to be linked to a low traffic environment where the free routing will be possible, while introducing a structure implies some constraints to the traffic:

- **Non-structured:** The lack of structure means that the area of the drone operation is an environment considered favourable for the vehicle/ Drone Operator itself to manage the separation responsibility.
- **Structured:** Structured are deployed in areas with higher demand. To balance the demand and the capacity it is assumed to be a need to impose certain restrictions in order to maintain the required safety level will arise. According to the conclusions in section 6, two type of structures are considered:
 - **Layers.** Since this structure design provides the possibility to accommodate drones equipped with different performance characteristics, centralised separation management is considered the safer option.
 - **Tubes/Corridors.** The aim of this structure is to increase predictability of traffic flows by means of pre-planned conflict free routes. Therefore, self-separation can be applicable provided that the vehicle comply with the required performance (mainly navigation) to ensure the required level of trajectory conformance. The preference in this case is that self-separation is implemented at the level of DO system.

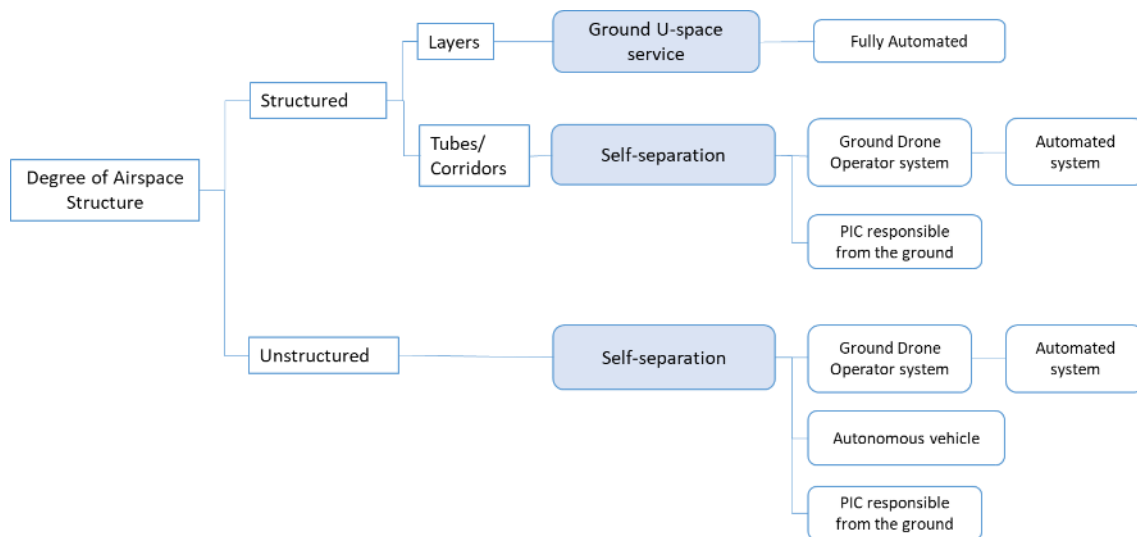


Figure 13. Criteria for the degree of the airspace structure.

7.2.5 Traffic Organisation (segregated/integrated)

The traffic organisation is important to establish the separation criteria. There are two possibilities considered:

- **Fully segregated:** In this airspace the flights will have similar characteristics so the separation management responsibility can be placed in the vehicle.
- **Integrated:** When different type of traffic is flying in the same area is more complicated to manage the separation so as the complexity grows this responsibility goes from the vehicle to the ground U-space service in order to maintain the required safety levels.

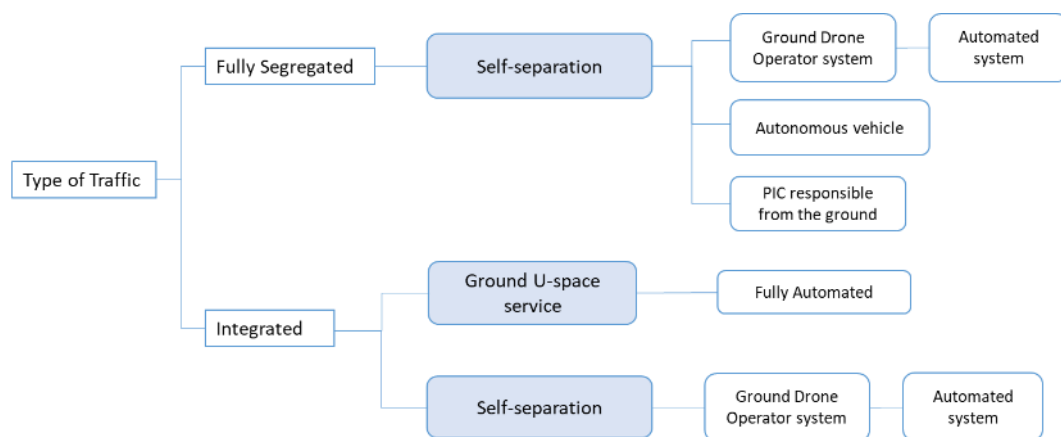


Figure 14. Type of traffic criteria.

7.2.6 Type of Area

Sometimes it may happen that certain amount of airspace is reserved for some specific activities. In this case the separation scheme will depend on the said activity and the type and number of drones:

- **Self-Separation:** When there is an exhibition or a demonstration with many drones involved, they are usually organized and self-separation will be involved.
- **Centralised Separation by Ground U-space Service:** This will apply to cases when not all vehicles in the reserved area are operated by the same entity. For example, if there is an accident and different kind of drones are in the scene: police, medical, firefighting. In this case, each kind of drones may be performing different tasks with barely interaction between them (the police drone is watching, the medical one is with the patients and the firefighting inspecting the accident zone).
- **PIC responsible from the ground:** This option is the one that applies in cases that one single drone is using the reserved area; for example, if a film crew has reserved some airspace to record a movie.

7.2.7 CNS performance level

The level of CNS performance in the area of operation will highly impact the drone performance itself. This factor has been divided in the three main type of technologies involved: air-ground communication, navigation and surveillance. In turn, these have been divided in two possibilities: **minimum service level** and **advanced capabilities**. The former refers to the minimum requirements that the CNS system has to fulfil in order to provide adequate service. The other possibility is that the CNS system meets the specified requirements and has additional capabilities that improve the level of service to the drone traffic.

TERRA project envisioned five levels of performance for each of the parameters considered in a technology type: from poor (0) to extremely good (5) [9]. In order to simplify the possibilities in this case, only two levels have been considered: minimum service level (corresponding to medium-good level) and advanced capabilities (corresponding to extremely good). Besides, for each type of technology, one or two performance parameters are selected as the ones to be considered as criteria for setting the performance scheme:

- Update rate and latency for air-ground communication;
- Accuracy and integrity for navigation;
- And update rate, accuracy and integrity for surveillance technologies.

When the advanced capabilities are present all the decision branches are considered, whereas when the technology performance only meets the minimum service level, vehicle self-separation for autonomous drones is out of question.

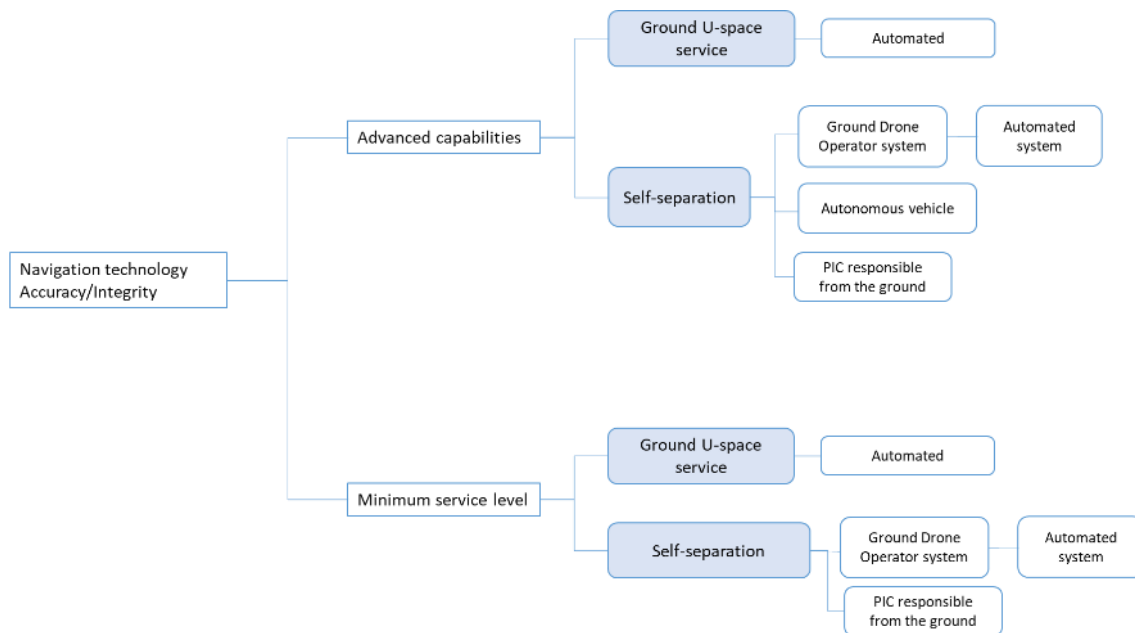


Figure 15. Navigation Performance criterion.

The previous figure shows the used criteria for navigation technology considering the most important parameters accuracy and integrity. The same scheme is applicable for communication and surveillance having update rate and latency, and update rate, accuracy and integrity as the most relevant parameters respectively.

7.2.8 Weather

The effect of weather conditions depends on the type of vehicle and its operational characteristics. Its acceptable ranges must always be linked to other criteria, so this decision factor must be understood as **relative weather** in contrast to absolute weather.

According to vehicle specifications and operational ranges, we define three types of weather:

- **Nominal weather** - far below weather operational limit for the specific vehicle;
- **Off-nominal weather** - outside but close to operational limit for the specific vehicle;
- **Extreme weather** – putting highly at risk the safety of the flight.

Weather also impacts the successful execution of specific missions. As an example, an infrastructure inspection that requires the drone to actually sense and touch the infrastructure, might not be feasible under off-nominal weather or might even require very particular weather conditions to be executed.

In this case, it is within the scope the Drone Operator to decide⁹ if the operation is feasible or not; weather that is not optimal from an operational point of view, but not a threat to maintain separation, is not impacting the decision of the separation management scheme.

When operating in nominal conditions all the possibilities can be applicable. The specific responsibility will depend on other factors as described before.

Autonomous drones in self-separation are not an option in off-nominal weather. This decentralised option implies higher uncertainty in the interactions between vehicles, and thus is considered not safe in off-nominal weather situations.

Finally, when the weather is considered extreme, the operation must be cancelled because the conditions are not acceptable to assure the safety of the mission.

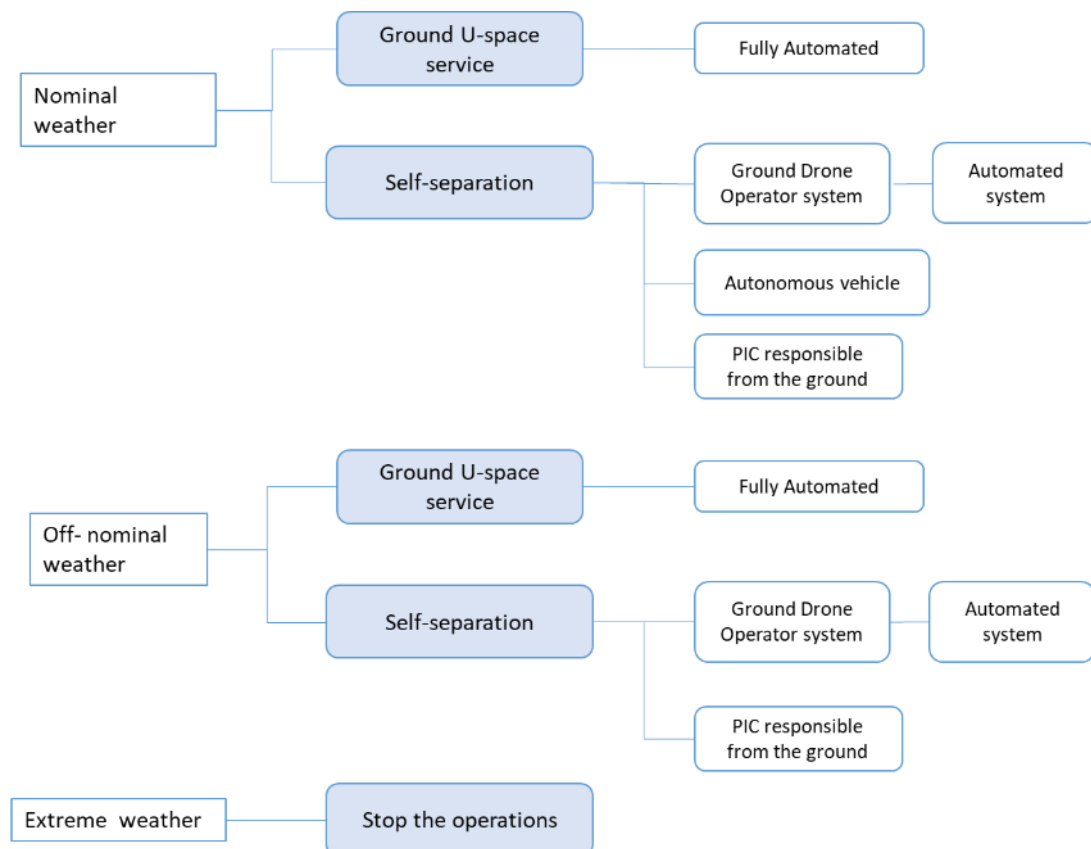


Figure 16. Weather criterion.

⁹ It can be envisaged that sophisticated systems will include specific weather services providing advice to Drone Operators on the feasibility of their intended missions, building on customised decision trees.

7.3 Ranking of the Criteria

Regarding the ranking of the Criteria, it has turned out to be a difficult task, as it has been seen that each criterion can have different importance depending on the scenario the drones are operating in, and the high level of interdependencies between them, so some options would be out of the decision tree when entering by a given criteria.

After all the analysis performed and shared in this document, several meetings have been held in order to give a final step, and try to reach any conclusion on how to rank all the decision criteria considered, in some kind of Delphi Method. And the conclusion reached is that there is no a unique solution. This means, there's no way of analytically stating a concrete rank for the decision criteria.

It has been concluded that there is a bunch of valid rankings, each one with their pros and cons. So, to dig deeper in this way, simulations and experiments are considered necessary. To define a ranking with the support of simulation results also data from proof of concepts (not yet available at this stage) would be needed, in order to support the appropriateness of the most promising rankings, helping to discriminate the best from the whole possible combinations of them. The results of all the debates motivated the survey which results are shown in Appendix B, in a way to try to find a workaround that would support on data a candidate ranking. The results of the survey, though throwing more light to the discussion, cannot be considered conclusive due to the low number of participants on the survey (only 8, despite they were very well instructed in the matter evaluated). However, as an example to kick-off simulation efforts with a tentative ranking based on the punctuations given in the survey is shown in the table included in the Figure below (as commented at the beginning of section 7.2, "Population Density", initially included in the survey, was deleted from the final ranking):

Ranking	CRITERIA	1	2	3	4	5	6	7	8	9	POSITION
1	Type of vehicle	3	1	1	2		1				2,8
2	Type of flight	1	1	2	2		2				3,6
3	Number of operations	1	3				3	1			4,0
4	CNS performance	1	2	1	2			1	1		4,4
5	Meteorology	1			2	2		1	1	1	5,4
6	Type of traffic	1		1		2		2	1	1	5,6
7	Form of the area				1			3	4		7,1
8	Type of area			1			1		1	5	7,8

Figure 17 Ranking of Decision Criteria extracted from the Survey on Appendix B

8. Next Steps

This deliverable is a modest attempt to provide inputs to the question of how to perform separation management in the tactical phase in drone operations. It provides a **conceptual approach** to the matter, contextualised in a particular environment (medium to high density operations in urban areas) and time horizon (the one when technology is assumed to be mature enough as to allow full automation of ground U-space services and the operation of autonomous vehicles).

A conceptual framework has been set proposing a number of **principles for the separation management** (section 3), encompassing the simultaneous operations under different separation management schemes and the trade-off between centralisation of separation and other aspects, such as automation level of both systems and vehicles. The focus has always been set to maintain a Target Level of Safety (TLS). Finally, the deliverable has proposed a list of potential criteria to be evaluated at mission/operation level which will provide the navigation key through a decision-tree resulting in the prescription of the most flexible separation scheme above the TLS. The goal is that free routing and self-separation are offered as much as safety permit.

Specific Research Challenges

From this point on, as it has been already mentioned in section 7.3, **simulations are needed** to further progress with the development of the Separation Management process. Main challenge is to validate the feasibility and benefits of the concepts proposed along the document, up to even deriving a specific ranking of criteria optimum both for safety and operational efficiency. Besides, some specific challenges have already been identified in this work:

- When considering the number of operations as a criterion (section 7.2.3), it is important to put the focus on **emergencies/ contingencies** and how they would be managed in each case in order to decide if the separation responsibility set would be able to cope with the situation safely. As an example, a low number of operations might seem a safe situation so as to allow a great level of de-centralisation in the separation management; but if contingencies are planned to be managed with substantial support from ground U-space services, then the separation management should be planned in a more centralised way even in nominal situations, as to avoid unsafe transitions from de-centralise to centralise management when contingencies appear.
- In line with the previous comment, **transitions** need to be tackled with carefully. A particular case will be that of the transition from unstructured to structured airspace (section 7.2.4) If dynamic airspace structures are on the table, it is key to detect the need for more structuring with enough time in advance so as to allow a smooth transition and handling of separation responsibility if applicable. For the handling of responsibility the current hand over between two ANSPs in ATC can be an inspiration.

The degree of airspace structure is furthermore a criterion with close dependencies with the number of operations. It might result that above certain number of operations with integrated traffic (section 7.2.5) the structure of the airspace is a must to maintain safety.

- Regarding traffic organisation (section 7.2.5), it is likely that even when a mission is going to operate in a segregated area, the drone will have to cross integrated areas at some point. This may lead to having **changes in the separation responsibility along the flight**, and again transition is a tricky part specially when the drone exits the segregated area and have to cope with transferring the separation responsibility to a central entity.

Separation Management and Conflict Detection & Resolution

Separation management breaks into two activities:

- 1) Conflict prediction (or detection);
- 2) Conflict resolution.

It is acknowledged that the focus of DACUS D5.2 is more on conflict resolution and the centralisation discussion might produce different results for conflict prediction.

There might be an overlap between conflict prediction and the provision of traffic information (as defined in the U-space regulation [6]). Traffic information picture (either built by a CISP or by an inter USSP platform via discovery and synchronization services) can also be seen as an ***enabler for the conflict prediction***. Once this common traffic picture is made available in real time to all concerned roles (including DOs), conflict prediction can still be performed in a de-centralised way by the DO or PIC.

For deciding on the suitability of the de-centralised approach, the threshold for each criterion would be different for conflict prediction and conflict resolution:

- It can be envisaged a greater level of centralisation needed for an effective conflict detection (requiring a longer time horizon ahead and wider area of interest),
- than the one needed for resolution (more focussed on the shorter time horizon and a closer area).

On-going Simulations and Proofs-of-Concept

Finally, it is worth highlighting a couple of initiatives that are already analysing the impact of certain criteria on separation management (for both of them contacts has been produced in the framework of DACUS project):

- Metropolis II project (<https://metropolis2.eu/>) develops solutions to strategic deconfliction, tactical deconfliction and dynamic capacity management, and in particular:
 - o Develops a *unified design approach* to the management of traffic in high-density urban airspace on all timescales, based on the segmentation and alignment principles of **geovectoring**, in combination with flight planning and detect and avoid paradigms that are designed to leverage the alignment principles from geovectoring, to define robust and efficient flight plans, as well as safe and compliant resolution strategies, which are suitable for operation in a densely-used airspace.
 - o Determines the benefits and drawbacks, via simulations, of *separation management paradigms* with different approaches to who acts as separator: the drone, the U-space service, or a combination thereof, and different combinations of procedural and tactical separation.

- VILAGIL project, a public-private partnership set up for the development of UAM co-funded by Toulouse Métropole (partner of DACUS and this task T5.3). The VILAGIL project involves four UAM action points, including the development of the Franczal Intermodality Test Centre which will be used for the development and testing of ground and air future mobility systems. As part of the demonstration activities within VILAGIL (2019 to 2029) they are included proofs of concept for separation management of drones in tactical phase according to the various urban (including drones) traffic management governance models considered.

9. References

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- [7] DOMUS project, D1.1 “Study Plan”, June 2019, SESAR Grant Agreement number SJU/LC/0341-CTR
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[16] COMMISSION IMPLEMENTING REGULATION (EU) 2020/639 of 12 May 2020 amending Implementing Regulation (EU) 2019/947 as regards standard scenarios for operations executed in or beyond the visual line of sight

Appendix A Survey of Automation Level of Drone Operations

Question	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6	Operator 7	Operator 8
Allocation in operation type	Mixed	• Surveillance • Inspection	• Surveillance • Inspection	Surveillance	Surveillance	Surveillance	Surveillance	Surveillance
Required automation level, operation mode and DAA capabilities	High Automation, BVLOS, D&A	High Automation, BVLOS D&A	Low Automatiuon, VLOS	Low, VLOS	Partial Automation, BVLOS	Partial Automation, BVLOS	High Automation, BVLOS, D&A	High Automation, BVLOS D&A
Required trajectory modelling and involvement of the pilot	4D	3D .	Pilot operated (FPV)	Pilot operated (FPV)	Pilot operated (FPV)	4D	Pilot operated (FPV)	3D

Question	Operator 9	Operator 10	Operator 11	Operator 12	Operator 13	Operator 14	Operator 15	Operator 16
Allocation in operation type	Surveillance	Surveillance	Inspection	Inspection	Inspection	Inspection	Transport	Transport
Required automation level, operation mode and DAA capabilities	Low, VLOS	Low, VLOS	Low, VLOS	Partial Automation, BVLOS	Low, VLOS	Partial Automation, BVLOS	High Automation, BVLOS, D&A	High Automation, BVLOS, D&A
Required trajectory modelling and involvement of the pilot	Pilot operated (FPV)	4D	Pilot operated (FPV)	3D	3D	Pilot operated (FPV)	2D	3D

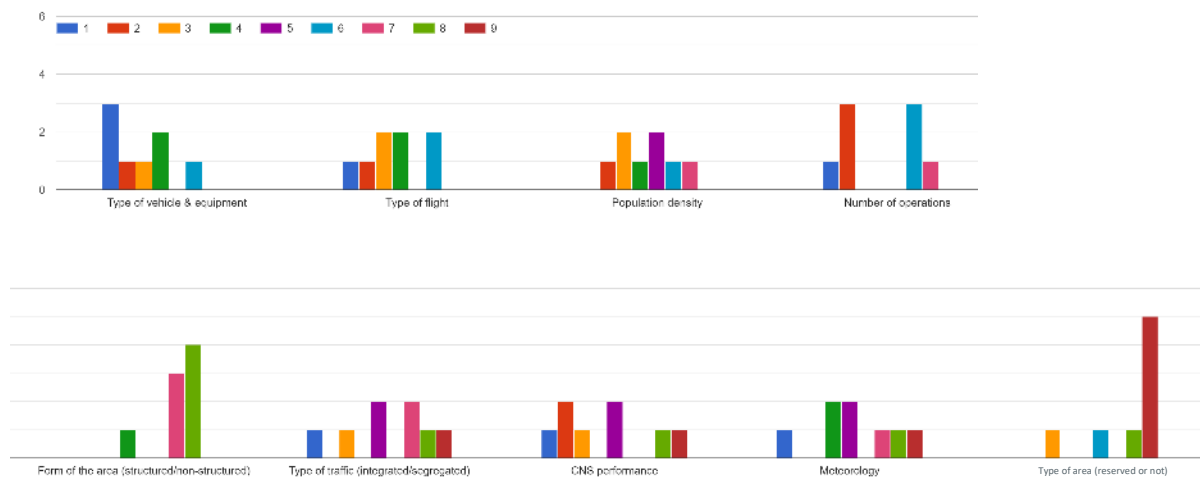
Appendix B Survey on Separation Decision Criteria

A survey has been conducted internally within DACUS project to complement the views of T5.3 partners on the analysis of decision criteria for setting the applicable separation scheme at mission level. This appendix provides a summary of the answers to each proposed question. The results have been used to refine the contents for section 7.2.

As indicated in section 7.2, since the survey was launched in parallel with the deliverable the list of criteria considered here is not 100% coincident with the list finally included in the later. Some criteria have been re-formulated conceptually and one of them has been finally discarded in the final list included in this deliverable. It is the case of the “Population Density”, which is a dynamic parameter implicitly included in the level of risk for a given area, which is already the trigger of the Separation Management process by DCB (see section 5).

B.1 Question 1.- Ranking of Criteria

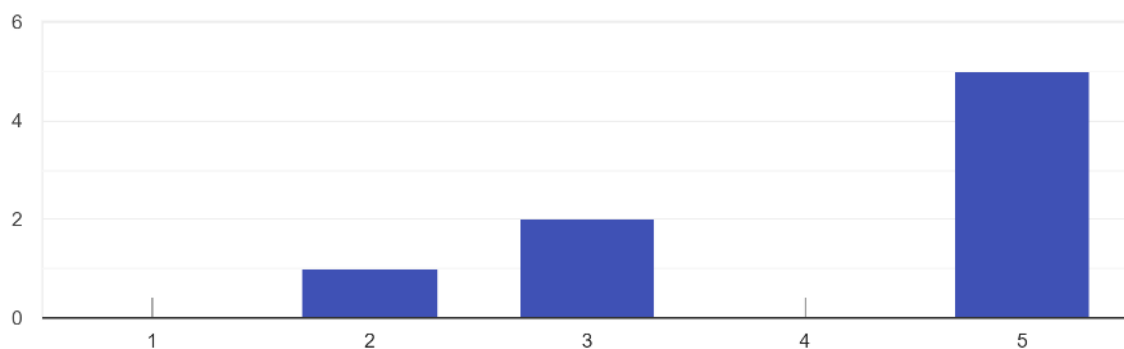
Rank the decision criteria according to their relevance, being 1 the most relevant and 9 the less.



B.2 Question 2.- Level of Relevance & Justification

Results for each criterion over 8 answers, being 5 higher relevance and 1 lower one.

B.2.1 Type of vehicle & equipment of the drone



Free text answers:

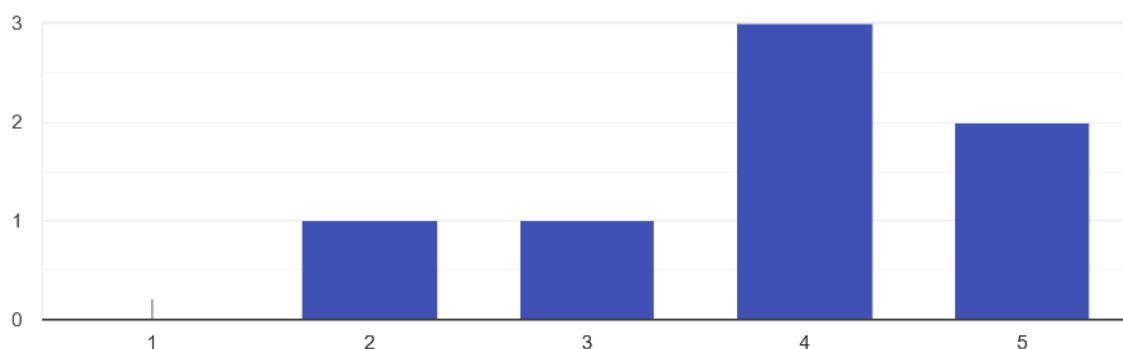
Why do you think that?

- It determines the technological capabilities and flight characteristics of the drones.
- The type of vehicle defines its capacity to manoeuvre in case of avoidance of collision, also somehow provides information on the payload (e.g., passengers).
- Equipment provides information on the capacity of the vehicle to detect, avoid, navigate with precision, provides its position with more or less accuracy, etc.
- The type/equipment is in principal linked to its CNS capabilities.
- Depending on the equipment of the vehicle, the capabilities of vehicle in reacting to separation management can look very differently.
- Performance (velocity, configuration, rate of turn...) of the vehicle will determine the speed of reaction to the conflict/distance travelled during the avoidance manoeuvre.
- Vehicle type including Size, weight and tech capabilities need to be considered.
- Safety measure in legacy aviation are for all type of aircraft.

How do you foresee the impact of the possible types of vehicles and equipment in the selection of the separation responsibility?

- Drones with an Advanced Equipment, e.g. Sense and Avoid, could obtain a higher responsibility of keeping separation but also be allowed to fly with a minimal separation.
- I do not foresee any impact of the type of vehicle and equipment on the separation responsibility.
- The type/equipment is in principal linked to its CNS capabilities, and ultimately its capabilities to assume separation responsibilities.
- High impact.
- The equipment of each aircraft will determine the capacity of detect other aircrafts and self-separate.
- Risk in case of crash depend of the mass.

B.2.2 Type of Flight



Free text answers:

Why do you think that?

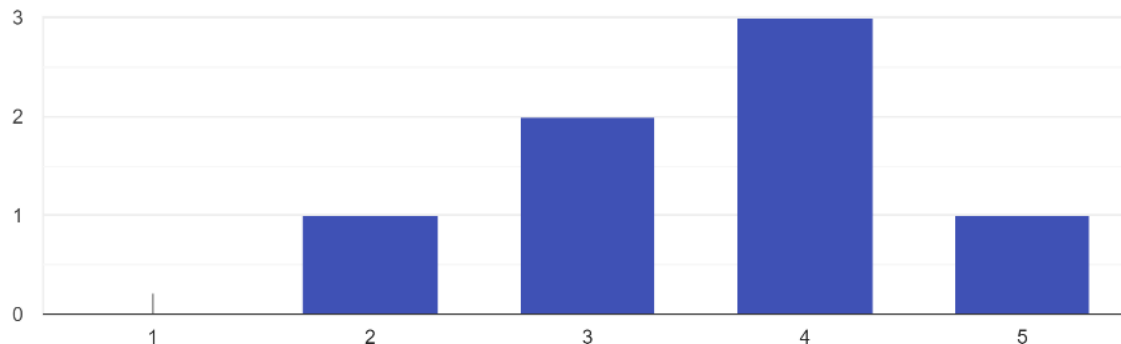
Founding Members

- As I understand this is not about the characteristic but e.g. the priority? But even if it's about the characteristic, let's say a very localized inspection of a facade, separation rules could be strongly affected by this information.
- In VLOS, the PIC shall be responsible for separation with all aircraft, helped by traffic information/situational awareness provision if necessary.
- In BVLOS, PIC and/or the vehicle shall be responsible for separation provided that they receive appropriate and required information and instructions.
- Ignoring emergency situations, the type of flight needs to abide by the rules just like any other flight.
- To me, it is a decisive factor if the flight is VLOS and pilot operated or controlled from the ground.
- Type of flight will have an impact in separation. However, it should not be a determinant factor as the operator must find the way to achieve the separation minima required, that is, separation minima must be set and then, depending on type of flight, the way of achieving it will vary.
- One the one hand, if an operator wants to fly in a congested airspace in VLOS, separation minima cannot be adapted to that (capacity will be drastically reduced) but the operator must find the way to assure safety or flying in other airspace/time. On the other hand, in a non-congested airspace, VLOS flights can take place and separation can be adapted to them.
- Operator location and type of flight has direct impact on the separation management.
- Some flight can be postponed.

How do you foresee the impact of the possible types of flights in the selection of the separation responsibility?

- I would expect that prioritized flights are less restricted.
- I guess I answered this question above.
- Not sure.
- High impact.
- Depending on the capacity of detecting other, the operator must delegate/rely on a centralised system to keep clear. Leaving the responsibility only on the pilot, even in VLOS, it doesn't seem to be an option (for me) in urban environments.
- Some type of flight can be prioritized.

B.2.3 Population density



Free text answers:

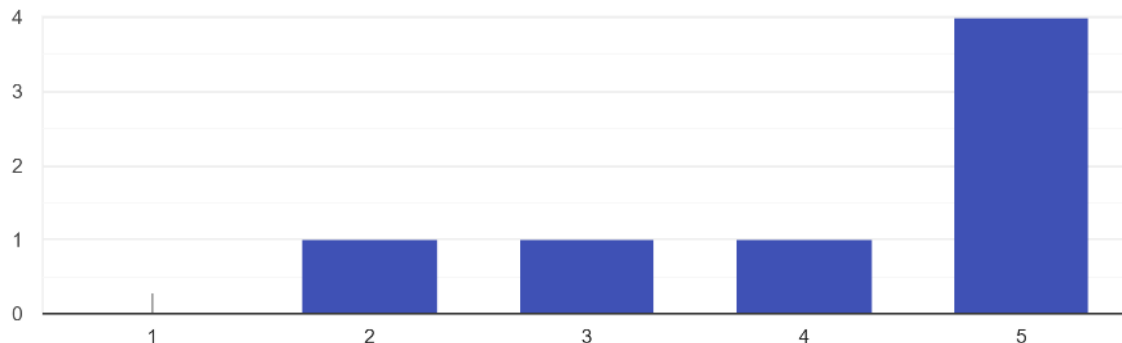
Why do you think that?

- Population Density as part of Risk Assessment should be covered in other principles already, like trajectory planning or capacity management.
- Due to the close proximity of the ground and people in urban environment, a margin may be taken in the separation standard minima pre-defined.
- From the safety aspect, or at least perception of safety, the population density should be considered.
- Due to its influence in the risk assessment.
- Population density will have an impact on the maximum risk on ground and, therefore, in separation to avoid collisions. However, risk on air must be also kept below a TLS and it is not affected by population density.
- Airspace structure and ground population density is another parameter to be considered while making decision.
- Direct impact with the level of risk.

How do you foresee the impact of the population density in the selection of the separation responsibility?

- It might be a factor still, but a very general one - high densities leading to strong separation restrictions.
- I do not any impact.
- Very dense population is linked to the necessity to have several layers of separation responsibility in the air.
- Normal impact. If it was agreed that the risk has become the trigger to apply a new separation scheme. Does the population density is not already a factor taken in consideration for the risk assessment?
- Only if the required separation minima can only be achieved by this means.
- To be linked with risk assessment.

B.2.4 Number of Operations



Free text answers:

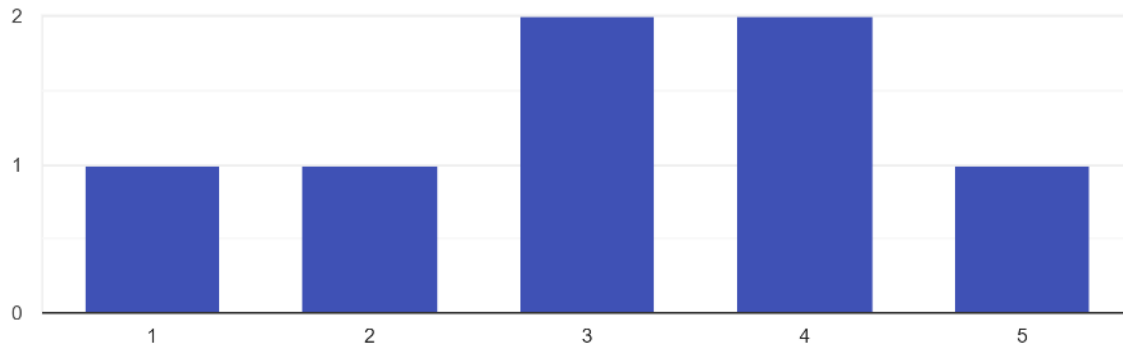
Why do you think that?

- Inherently important, separation management is directly linked to the number of ops.
- The separation minima will define a maximum capacity of the airspace in a given condition.
- The separation minima is supposed to insure a minimum safety level. This should not depend on the number of operations.
- Due to its link with density of operations and associated risk.
- Number of operations will determine how structured must be the airspace. Moreover, in certain airspaces, some means of separation maybe are not allowed given the high density of traffic.
- Airspace Capacity is important for definition of separation
- Density.

How do you foresee the impact of the number of operations in the selection of the separation responsibility?

- The more flights the more management / responsibilities.
- No impact.
- Normal, but to me, in a decision process, this criteria should come after other criteria like airspace structure because then the capacity looks differently.
- In congested airspace, some means of separation such as self-separation could not be allowed.
- Like with density of population also.

B.2.5 Form of the area (Structured/non-structured)



Free text answers:

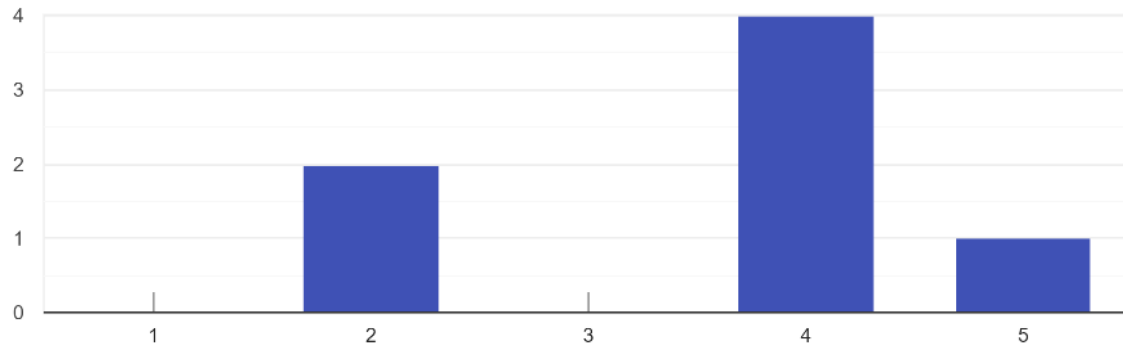
Why do you think that?

- If not reflected enough in the general planning of operations, it could become relevant.
- It depends if we want to include the notion of geo-awareness. Anyway, PIC and/or vehicle remains responsible for separation unless USP does not provide required information/instructions.
- The more structure an airspace has, the more predictable the aircraft flows and separation.
- Certain structured airspaces can already provide a separation between the vehicles.
- Once the airspace structure is set, the means to achieve it should not be determined by it.
- Can be organised with specific rules.

How do you foresee the impact of the form of the area in the selection of the separation responsibility?

- The less the area is structured the more management of separation is needed.
- I do not foresee any impact.
- Unstructured areas will require aircraft to assume more self-separation responsibility.
- High impact.
- I don't see the point.
- Possibility to establish routes like in legacy.

B.2.6 Type of traffic (Segregated/ Integrated)



Free text answers:

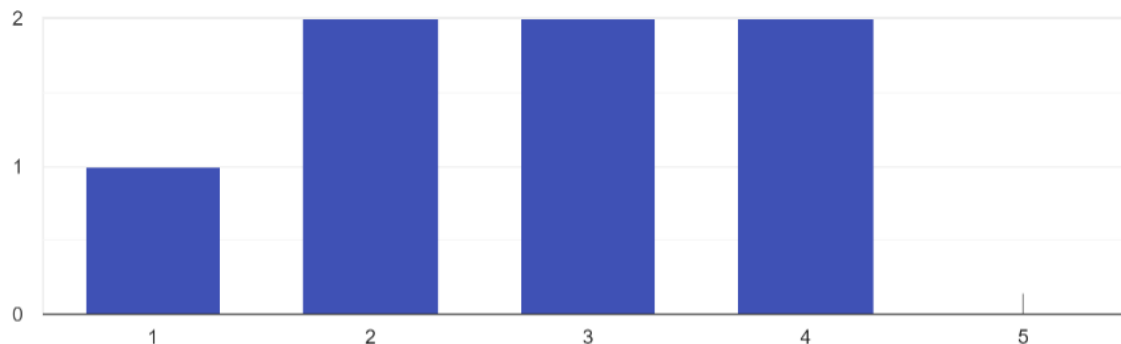
Why do you think that?

- A very universal factor, it is either segregated or integrated.
- It depends why the traffic is segregated; otherwise not that much relevant.
- The more mix of types, the more separation strategies are presumably required.
- Having traffic with homogenous characteristics can facilitate the application of separation schemes.
- I don't see the point.
- Type of traffic will allow in defining the risk involved with the operation.
- Must integrate legacy rules.

How do you foresee the impact of the type of traffic in the selection of the separation responsibility?

- Integrated traffic needs a very strong management of separation with high responsibilities on all sides.
- Same answer as above, and PIC and/or vehicle remains responsible for separation unless USP/ATC does not provide required information/instructions.
- A large mix of traffic will presumably require aircraft to assume more self-separation responsibility
- High impact.
- I don't see the point.

B.2.7 Type of Area (Reserved or not)



Free text answers:

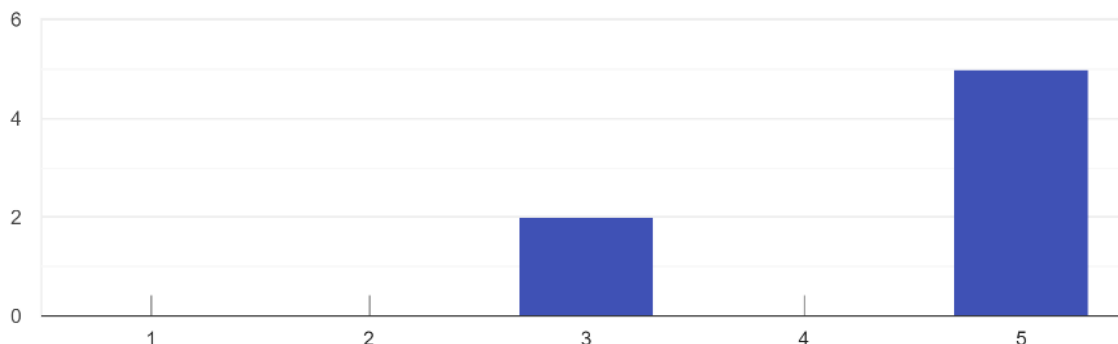
Why do you think that?

- I assume the number of operations in reserved airspaces will be low, so I don't think it will be relevant in _total_. But it can become very relevant for specific operations.
- It depends if we want to include the notion of geo-awareness. Anyway, PIC and/or vehicle remains responsible for separation unless USP does not provide required information/instructions.
- Reserved airspace will have its own rules and presumably be a lot less dense.
- In the way I understood the definition of reserved airspace, such airspaces are likely to take place in urban environments frequently.
- I don't understand it very well.

How do you foresee the impact of the type of area in the selection of the separation responsibility?

- If applicable, the impact can be very specific / high.
- No impact
- I see this more as a pre-tactical and strategy phase, and (2) aircraft allowed in reserved airspaces will likely have to meet multiple criteria to be allowed in.
- High impact.
- I don't understand it very well.

B.2.8 CNS Performance



Free text answers:

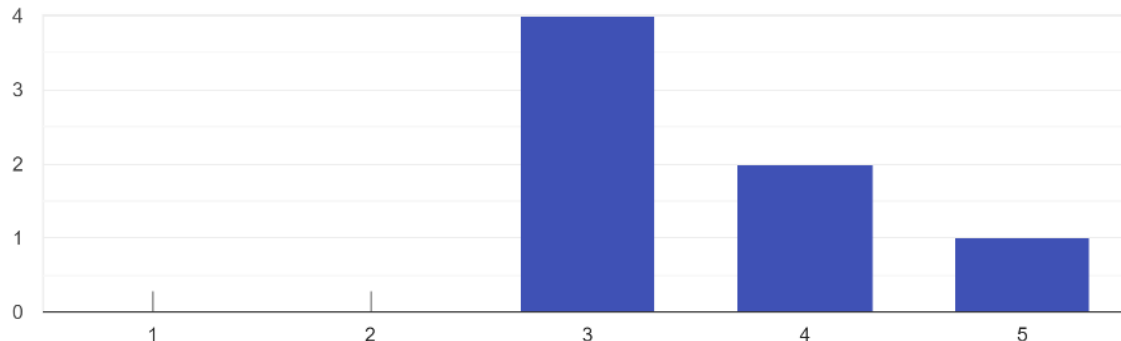
Why do you think that?

- More important for low-capability drones and external management. Less relevant for high autonomy vehicles I assume.
- Navigation accuracy, communication and surveillance are the basis to get accurate position of the aircraft, allow the drone to be steered or receive required information on time, and eventually detect failure in the navigation systems...
- The CNS will be a fair part of the ability of the aircraft to self-separate and/or assume separation responsibilities.
- Because its influence in vehicle self-separation.
- The capability of the drone to determine its position and the position of other aircrafts will be essential to determine the responsibility of separation.
- Like meteo, CNS performance is predefined.
- Like in legacy we can imagine specific certification like CAT III for example.

How do you foresee the impact of the CNS performance in the selection of the separation responsibility?

- The worse the CNS capability, the more responsibility the operator has, since external management might be more difficult.
- No impact. Once the vehicle is the air, the aircraft is under the responsibility of the PIC, whatever the shape it could have.
- Very high impact.
- The capability of the drone to determine its position and the position of other aircrafts will be essential to determine the responsibility of separation.
- To be considered to minimise separation.

B.2.9 Weather



Free text answers:

Why do you think that?

- Atmospheric conditions determine flight capabilities, sense and avoid capabilities (fog/rain and detection systems don't work well together) and air/ground risk very dynamically. Ergo it's very relevant.
- Meteorology may impact some CNS systems and the capacity of the vehicle to manoeuvre on time.
- For many aircraft types, the weather forecast may have an impact on their ability to fly and/or ability to manoeuvre safely.
- Because adverse weather conditions can already affect a wide range of drone types.
- Meteorology has a great impact in the separation management and separation minima as it affects visibility, manoeuvrability...
- Meteo data is subject of accuracy and operator already simulate in real environment.

How do you foresee the impact of the weather in the selection of the separation responsibility?

- Individual monitoring and assessment of weather impacts are needed in the selection of separation responsibilities.
- No impact; same argument as above.
- The more extreme the weather (rain and/or wind), the more consideration needs to be given to separation strategies and the ability to assume separation responsibilities.
- Normal/low impact.
- Certain meteorological conditions will not allow some separation schemes such as self-separation.

B.3 Links between Decision Factors

What do you think the criteria are linked with? More than one option can be selected.



B.3.1 Link between type of vehicle & equipment of the drone and other criteria

- Weather and CNS performance are directly linked to the vehicle type.
- Equipment and CNS is obvious.
- For segregated area it is linked to the geo-awareness capability.
- For meteorology, equipment may compensate for instance strong wind during the navigation.
- Type of equipment influences the CNS capabilities, and where and if a flight may fly in certain regime.
- Type of vehicle and equipment will determine which type of flight can be performed.
- Capability.

B.3.2 Link between type of flight and other criteria

- There could be a secondary link between ToF and reserved airspace / number of operations, but I don't think relevant in the separation context.
- Type of flight may not be desirable or able to fly in extreme weather.
- Same as above.

B.3.3 Link between population density and other criteria

- See previous answer.
- Separation may be increased over densely populated areas. Equipment and CNS are involved.
- As the population density increases, it may require more structure, integration, and capacity limits to provide a safe airspace above the population.

B.3.4 Link between number of operations and other criteria

- The worse the Wx conditions the less operations and the more restrictions are likely.
- The number of operations increases, more situational awareness is required, and/or constraints such as airspace structure.
- Demand will depend on the meteorological conditions and the type of aircraft the operator has.

B.3.5 Link between form of the area (structured/ non-structured) and other criteria

- As the complexity of an area increases, it may require more structure, integration, and capacity limits to provide a safe airspace above the population.
- Density of traffic, type of drone and flight will determine the risk of the scenario which will derive the structures of airspace.

B.3.6 Link between type of traffic (segregated/ integrated) and other criteria

- Linked to geo-awareness capability.
- As the population density increases, it may require more structure, integration, and capacity limits to provide a safe airspace above the population.
- The equipment of the drone or the "sensitivity" of the operation will determine if the airspace must be segregated.

B.3.7 Link between type of area (reserved or not) and other criteria

- Linked to the type of traffic if the airspace is reserved to protect the aircraft and payload for instance.
- Reserved airspace may require certain types of flights, and/or may be implemented during a large population density event.
- The equipment of the drone or the "sensitivity" of the operation.

B.3.8 Link between CNS performance and other criteria

- CNS and Weather go together, e.g. degradation of Navigation Capabilities. Same with the equipment and CNS.
- See answers above for population density and equipment.
- CNS performance defines the ability of the aircraft to provide separation responsibility and situational awareness, especially in more complex or dense airspaces.
- Meteorology (bad conditions) can affect CNS signals.

B.3.9 Link between weather and other criteria

- See previous answers.
- See answer in the equipment field.

- Extreme weather may instigate a reserved airspace to generally avoid or to be selective about what aircraft can enter the reserved airspace.