Report

Safety assessment of UAS operations in civil CTRs

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1 PREAMBLE

This safety assessment is commissioned by the Unmanned Aviation Program of the Ministry of Infrastructure and Water Management and addresses the potential hazards and safety risks associated with the operations of UAS in the vicinity of civil airports in The Netherlands, i.e., in the control zones (CTR). The assessment is to be considered as a preliminary safety assessment since it addresses a high-level concept of UAS operating in the CTR.

The safety assessment takes a two-sided approach, on the one hand looking at the safety risks from a manned aviation perspective and on the other hand looking from the perspective of the UAS operations through the application of the air risk part of the Regulation (EU) 2019/947 Specific Operations Riks Assessment (SORA) methodology.

2 DESCRIPTION OF THE OPERATIONAL CONCEPT

2.1 Concept design criteria

To assure safe operations of manned aviation in the vicinity of the civil airports Control Zones (CTR) have been defined. In these CTRs the rules of the air apply as published by EASA (see 3.1.1). Air Traffic Control the Netherlands (LVNL) is the designated Air navigation Service Provider (ANSP). The CTRs of Schiphol (EHAM), Rotterdam (EHRD), Groningen (EHGG) and Maastricht (EHBK)are airspace class C, the Lelystad (EHLE) CTR is airspace class D. In class C airspace, flights operating under Visual Flight Rules (VFR) are separated from traffic operating under Instrument Flight Rules (IFR).

Currently UAS operating in the civil CTRs are considered as VFR traffic since no other regulatory definitions are currently available. Separation from IFR traffic in the class C CTRs are the source of extra workload for the aerodrome controller. To manage traffic in the CTR in a safe way and simultaneously manage the workload of the Air Traffic Controller (ATCO), additional procedures have been established (e.g., 2-way radio contact) and the number of UAS that may be accommodated in the CTR is limited. These procedures and limitations are restrictive for UAS operators.

The development of the concept to accommodate UAS in Very Low-level Airspace (VLL) within the lateral dimensions of the civil CTRs is set up in an iterative way between operational innovative ideas and identified safety considerations, safety by design. The MovingDot philosophy to help ensure safety-by-design is rooted in four key features; permissibility, achievability, desirability and feasibility of the application/implementation of the concept.

The leading concept requirements are

- Assure safety of manned aviation and UAS operations in the CTR.
- Design VLL UAS zones in the CTR where UAS can operate safely without the provision of Air Navigation Services (ANS) provided by LVNL, i.e., no Air Traffic Control (ATC), no Flight Information Service (FIS) and no Alerting Service (AS).

2.2 Concept design

The concept, is based on segregation of manned and unmanned operations. To achieve this, VLL UAS zones will be designed that are laterally and vertically dimensioned in such a way that IFR and VFR traffic will be at sufficient distance from the UAS operating areas, the geographical separation principle[1]. The concept is based on the standard IFR and VFR flight profiles.

In the CTR, UAS zones are designed (Figure 1) in which operating conditions for unmanned aviation are set depending on the safety sensitivity of the area concerned. In zones 2A and 3, UAS may operate without involvement of ATC. In the remaining airspace (UAS zones 1, 2B and 4), ATC will provide Air Traffic Services (ATS).

Zone 1

- Consists of the airport including a buffer area of 2 kilometres from the airport's perimeter laterally and GND - 120m/400ft[2] AGL vertically.
- Manned traffic concentrates in this area at low altitudes and is in its most safety critical part of flight.
- UAS operations in this zone are controlled by ATC.

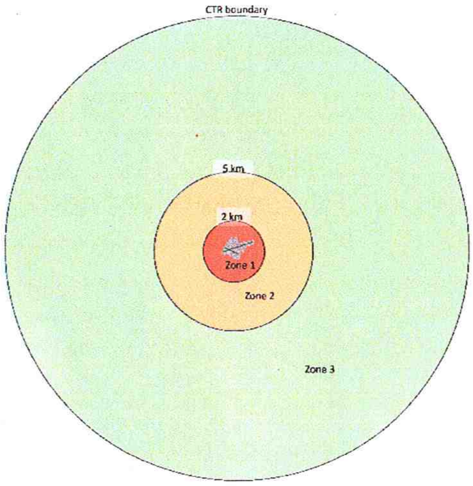

Figure 1 Conceptual zoning of the CTR

Zone 2A

- This is the intermediate zone that extends from the outer edge of zone 1 till 5km from the airport's perimeter laterally.
- UAS are envisaged to operate here at maximum height of 150ft/45m AGL without involvement of ATC.
- Regular manned traffic is not expected in Zone 2A.

Zone 2B

- This is the intermediate zone that extends from the outer edge of zone 1 till 5km from the airport's perimeter laterally.
- UAS are envisaged to operate here at maximum height of 400ft/120m AGL with involvement of ATC.
- Manned traffic flies higher and at a lower density compared to Zone 1.
- UAS operations in this zone are controlled by ATC.

Zone 3

- Zone 3 is composed of the outer zone of the CTR. It extends from the outer edge of zone 2 to the CTR boundary laterally and GND - 120m/400ft AGL vertically.
- IFR traffic generally operates here above 1500 feet (ft) and VFR traffic at or above 500ft.
- UAS are envisaged to operate here at maximum 400ft/120m AGL without involvement of ATC.

Zone 4

- Consist of the entire CTR above 120m/400ft AGL (not visualised in Figure 1).

[1] Geographic separation is lateral separation between aerial vehicles over specific separated geographical locations and/or in separated geographical areas.

[2] UAS operations refer for altitude to meters (m) above ground level (AGL), manned aviation in the Netherlands apply feet (ft) above mean sea level(AMSL). Therefore, vertical distances in this document will always be indicated in meters and feet simultaneously.

- Considered to be safety critical and thus controlled by ATC.

2.2.1 Vertical units of measurement

The airspace definition and all manned aviation procedures are established in feet AMSL. UAS operators and systems work with meter AGL. When defining the UAS zones of the various airports, this has been taken into account. This is especially relevant for EHBK that has an elevation of 375ft. However, the flight procedures at all five civil airports are defined in such a way that the concept design is applicable to all five, including EHBK without additional safety risks due to this difference in operationally used units of measurement.

3 SAFETY RISK ASSESSMENTS

3.1 Safety assessment airspace

For the safety assessment airspace, the standard assessment methodology for air navigation service providers is applied. Air Traffic Control The Netherlands (LVNL) and the Human Environment and Transport Inspectorate (ILT) are both familiar with this methodology that backed changed Air Traffic Management (ATM) processes and systems for years and therefore supports acceptance by both parties and increases the enforceability.

The methodology addresses the various manned traffic flows and functions, projecting them on those concept items that are changed compared to the current operational situation and looking at potential hazards, associated safety risks and adequate mitigating measures when needed. For the safety risk matrix, see Annex A.

Note: There is currently not sufficient reliable data available for a quantitative safety analysis with regard to UAS operation. Therefore, we assume a qualitative risk analysis for this safety risk assessment.

3.1.1 Relevant regulations

SERA.6001 Classification of airspaces
SERA.7001 Objectives of the air traffic services
SERA.8001 Application of air traffic services
SERA.8005 Operation of air traffic service
SERA.8015(a) Air traffic control clearances
SERA 9001 - 9005 Flight information service
SERA.10001 - 10005 Alerting service
See Annex B

3.1.2 Identification of traffic flows

The traffic flows that are taken into account for the safety assessment are:

- IFR flights following the SIDs (outbound traffic) or the published instrument approaches (inbound traffic).
- IFR flights that are not following the published IFR procedures.
- VFR flights following the VFR procedures (outbound and inbound traffic).
- VFR flights that are not following the published VFR procedures.
- IFR or VFR flight emergencies.
- VFR flights with a minimum flight altitude exemption[3/4].

3.1.3 Description of hazards

When several UAS operate randomly in the CTR without ATC supervision there is a real and imminent risk of collision between aircraft and the UAS.

Furthermore, aircraft induced wake turbulence poses a threat to the controllability of the UAS, preventing the UAS pilot to take action to avoid aircraft operating in its vicinity.

[3] Vrijstellingsregeling Besluit luchtverkeer 2014, Artikel 2.1 Minimum vlieghoogtes en Artikel 4.1 Luchtwerk

[4] Regeling minimum VFR-vlieghoogten en VFR-vluchten buiten de daglichtperiode voor militaire vliegtuigen en helikopters, Artikel 1,2, 4, 5, 6, 7, 8

3.1.4 Description of environmental conditions

When UAS are used in the vicinity of civil airports the following conditions apply and have been taken into account in the safety assessment:

- Control zone airspace classification C and D in which LVNL is responsible for the provision of Air Traffic Services.
- Manned aircraft operating under IFR and VFR.
- All weather conditions.
    - VMC - visibility ≥5km, cloud base ≥1000ft.
    - Special VFR conditions - visibility ≥1500m, ceiling ≥600ft.
    - IMC - visibility ≤1500m, cloud base ≤800ft.

3.1.5 Scope of the safety assessment

- The estimation of safety risks is based on the so-called worst-case scenarios.
- The safety risk assessment
    - focusses on operations of open and specific category, certified category UAS are not taken into account;
    - addresses the UAS operations in the UAS zones 2A and 3 only, i.e., UAS operations independent of ATC involvement;
    - does not differentiate for the various types of UAS such as multirotor/fixed wing/VTOL, low or high weight and their performances (e.g., low/high speed operations) as these are taken into account through the Ground Risk Class determination in SORA and this safety assessments (for the Air Risk Class) is based on worst-case scenarios (i.e., it is assumed a collision between any UAS and manned aircraft can be fatal)
    - concentrates on (E)VLOS operations since the regulatory framework for BVLOS operations in the Netherlands is not yet defined.
    - The safety risk resulting from unauthorised drone flights, i.e., drone flights that operate outside the available zones and/or do not abide by the rules set for drone operations in the CTR is not addressed.

Note:

Airspace definitions and associated flight profiles are defined in feet AMSL, UAS operations and authorisations in meters AGL.

3.1.6 Assumptions

When assessing the safety risks from a manned aviation perspective, the following assumptions were made:

- The quality of the UAS operations in the CTR (system and pilot certification) involved should not add additional safety risks to the concept.
- UAS operation in the safety critical parts of the drone zones will be conducted with UAS of reliable design and performance.
- UAS pilots operating in the CTR will be adequately trained.
- UAS pilots operating in the CTR will strictly follow the rules laid down for these operations.
- UAS inside the designated UAS zones 2A and 3operate independently, i.e., without involvement or interaction with ATC.
- 2-Way communication between UAS pilots and ATC, where applicable, is arranged and working (phone, app, R/T etc.).
- 500ft (150m) Vertical distance between IFR flights and UAS is considered to be acceptable for safe operations based on:

  - Standard vertical separation minima in class C airspace between IFR and VFR flights.
  - Adequate vertical distance to mitigate wake turbulence safety effects.
- At least 100ft (30m) vertical distance between VFR flights and UAS is considered to be acceptable for safe operations based on:
  - No separation is provided between VFR flights in airspace class C
  - SORA air risk criterion (flight geography 400ft, contingency volume 100ft)

  Note

  VFR traffic operates at a minimum altitude of 150m (500ft) whilst UAS operate at a maximum altitude of 120 m (400ft). This results in a minimum vertical distance between VFR flights and UAS of 100 ft in case they simultaneously overfly the same position.

  VFR pilots and UAS pilots are responsible for avoiding collisions. To do so, VFR pilots use the see and avoid principle. This requires pilots to actively search for potentially conflicting traffic, especially when operating in airspace where traffic is not operating under the instructions of ATC. For UAS pilots the same principle applies where see and avoid in practice means that the remote pilot will land the drone immediately when other air traffic approaches. These rules apply both in uncontrolled airspace and in the envisaged drone zones in the civil CTRs.

3.1.7 Prerequisites

- The UAS zone design is ICAO Annex 14 compliant, i.e., no independent UAS operations above the ICAO Annex 14 Obstacle Limitation Surfaces (OLS). See Annex C.
- UAS that operate in the CTR outside the designated UAS zones 2A and 3:
  - Require prior permission from LVNL (strategic planning).
  - Additional operational requirements to ensure safety.
  - Only Specific category UAS permitted, Open category UAS prohibited.

3.1.8 Wake turbulence

When UAS operate in the CTR UAS zones described in paragraph 2.2, manned traffic in this concept will fly higher than the UAS. Aircraft in flight cause wake turbulence. The heavier the aircraft the stronger the wake turbulence vortices it generates.

Helicopters generate rotor tip vortices that are relatively strong in relation to their weight and next to that helicopters produce rotor downwash that is perceived as turbulence by flying craft touched by the downwash.

There is no information available on how far below an aircraft/helicopter the wake will no longer be problematic.

Turbulence in general can have significant effect on the controllability of UAS. Turbulence can destabilise a UAS, causing it to roll, yaw or pitch unexpectedly. This can lead to altitude fluctuations that may take the UAS above the maximum operating height, thus creating an infringement of controlled airspace that may lead to insufficient spacing between manned aircraft and UAS.

9. Safety risk assessment table

Table 1 IFR traffic flight profiles

Controlled IFR traffic profiles	Operational hazard	Environmental conditions	Initial safety risk	Rationale/remarks/new mitigating measures	Predicted residual safety risk
IFR departure procedure	Insufficient spacing between aircraft and drone results in loss of separation	CTR airspace class C All weather conditions	I - risk of collision	Drone operations at least 150m/500ft below IFR flight Zone 1 - no drone operations Zone 2A - max. drone altitude 45m/150ft AGL Open category drones prohibited; specific category permitted Zone 3 - max. drone altitude 120m/400ft AGL	III
	Wake turbulence causes drone to be unable to stay in assigned sector	CTR airspace class C	II - risk of airspace infringement	Vertical distance IFR flight/drone minimum 150m/500ft	IV
IFR arrival procedure	Insufficient spacing between aircraft and drone results in loss of separation	CTR airspace class C All weather conditions	I - risk of collision	Drone operations at least 150m/500ft below IFR flight Zone 1 - no drone operations Zone 2A - max. drone altitude 45m/150ft AGL Open category drones prohibited; specific category permitted Zone 3 - max. drone altitude 120m/400ft AGL	III
	Wake turbulence causes drone to be unable to stay in assigned sector	CTR airspace class C	II - risk of airspace infringement	Vertical distance IFR flight/drone minimum 150m/500ft Drone pilots should be warned of the effect that wake vortices may have on the controllability of the drone.	II
Low altitude IFR flights that do not follow not on published SIDs or approaches	Insufficient spacing between aircraft and drone results in loss of separation	CTR airspace class C	I - Loss of separation	Drone operations at least 150m/500ft below IFR flight Zone 1 - no drone operations Zone 2A - max. drone altitude 45m/150ft AGL Open category drones prohibited; specific category permitted Zone 3 - max. drone altitude 120m/400ft AGL	III

Controlled IFR traffic profiles	Operational hazard	Environmental conditions	Initial safety risk	Rationale/remarks/new mitigating measures	Predicted residual safety risk
IFR flight emergency in CTR	Insufficient spacing between aircraft and drone results in loss of separation	CTR airspace class C	I	Zone 1 - no drone operations Zone 2A - max. drone altitude 45m/150ft AGL Open category drones prohibited; specific category permitted Zone 3 - max. drone altitude 120m/400ft AGL	II

Table 2 VFR traffic flight profiles

Controlled VFR traffic profiles	Operational hazard	Environmental conditions	Initial safety risk	Rationale/remarks/new mitigating measures	Predicted residual safety risk
VFR departures procedures	Insufficient spacing between aircraft and drone results in loss of separation	CTR airspace class C Outbound VFR traffic leaves the CTR according to the VFR procedure ≤300m/1000ft	II	Drone operations at least 30m/100ft below VFR flight Zone 1 - no drone operations Zone 2A - max. drone altitude 45m/150ft AGL Open category drones prohibited; specific category permitted Zone 3 - max. drone altitude 120m/400ft AGL	III
	Wake turbulence causes drone to be unable to stay in assigned sector	CTR airspace class C	III	Vertical distance aircraft/drone minimum 150m/500ft	III
VFR arrivals procedures	Insufficient spacing between aircraft and drone results in loss of separation	CTR airspace class C Inbound VFR traffic enters the CTR via the VFR procedure ≤300m/1000ft	II	Drone operations at least 30m/100ft below VFR flight Zone 1 - no drone operations Zone 2A - max. drone altitude 45m/150ft AGL Open category drones prohibited; specific category permitted Zone 3 - max. drone altitude 120m/400ft AGL	III
	Wake turbulence causes drone to be unable to stay in assigned sector	CTR airspace class C	II	Vertical distance aircraft/drone minimum 150m/500ft Drone pilots should be warned of the effect that wake vortices may have on the controllability of the drone.	II

Controlled VFR traffic profiles	Operational hazard	Environmental conditions	Initial safety risk	Rationale/remarks/new mitigating measures	Predicted residual safety risk
VFR flights that do not follow not on published VFR procedures	Insufficient spacing between aircraft and drone results in loss of separation	CTR airspace class C VFR traffic outside VFR routes ≤300m/1000ft≥150m/500ft	II	Drone operations at least 30m/100ft below VFR flight Zone 1 - no drone operations Zone 2A - max. drone altitude 45m/150ft AGL Open category drones prohibited; specific category permitted Zone 3 - max. drone altitude 120m/400ft AGL	III
VFR flight emergency in CTR	Insufficient spacing between aircraft and drone results in loss of separation	CTR airspace class C	I	Zone 1 - no drone operations Zone 2A - max. drone altitude 45m/150ft AGL Open category drones prohibited; specific category permitted Zone 3 - max. drone altitude 120m/400ft AGL	III
VFR flights with a minimum flight altitude exemption	Insufficient spacing between aircraft and drone results in loss of separation	CTR airspace class C Flight altitude <150m/500ft	I	Flights require ATC clearance to operate in the CTR ATC provides separation with manned traffic and drone traffic in zones 1, 2B and 4 according to the requirements for the airspace classification (C or D). ATC does not provide separation with drones in the drone zones 2A and 3 Publish information of the drone zones 2A and 3 in the AIP and insert a textbox with a warning to expect unknown drones' traffic in the aeronautical charts	III

Note

The resulting safety measures become safety requirements upon realisation of the concept and must be verified when the resulting operational concepts are implemented. If necessary, a monitoring plan should be drawn up. This enables verification that the implemented requirements and mitigation measures indeed reduce the classified risks to the predicted residual risk.

3.2 SORA air risk assessment

For the safety assessment from the perspective of an UAS operator, the Specific Operations Risk Assessment (SORA) methodology was used. As SORA both identifies (and mitigates) the risks on the ground and in the air, and this safety risk assessment only focusses on risks in the air, only the part of SORA that determines the Air Risk Class (ARC) was applied. The scope of the air risk assessment in SORA does not include:

a. the probability of UAS-on-UAS encounters; or
b. risks due to wake turbulence, adverse weather, controlled flight into terrain, return-to- course functions, a lost link, or an automatic response.

This air risk assessment is qualitative in nature. Where possible, this assessment will at a later point in time and when available, use quantitative data to back up and support the qualitative assumptions. The UAS operator and the competent authority should understand there may not be a clear delineation of the decision points, so common sense and the safety of manned aircraft should be of paramount consideration.

3.2.1 Definitions

As the Acceptable Means of Compliance (MoC) and Guidance Material of Commission Implementing Regulation (EU) 2019/947 of 24 May 2019 on the rules and procedures for the operation of unmanned aircraft do not provide definitions of two key airspace-concepts, the following definitions have been taken from Annex I of the JARUS SORA methodology:

Atypical Airspace: Atypical Airspace is defined as;

a. Restricted Airspace or Danger Areas;
b. Airspace where normal manned aircraft cannot go (e.g., airspace within 100 ft. of buildings or structures);
c. Airspace characterization where the encounter rate of manned aircraft (encounter is defined as proximity of 3000 ft. horizontally and ± 350 ft. vertically) can be shown to be less than 1E-6 per flight hour during the operation);
d. Airspace not covered in Airspace Encounter Categories (AEC) 1 through 12

Airport Environment: Airport environment is generally defined as;

a. Class A, B, C, D, or E controlled airspaces which touch the surface with an airport and/or controlled airspaces which do not touch the surface, but in connection to an airport (normally depicted on aeronautical charts and sectionals); or
b. Any Mode C Veil (US) or TMZ (Europe) in Class A, B, C, D, or E, controlled airspace; or
   c) 5 nautical miles from an airport having an operational control tower; or
c. 3 nautical miles from an airport with a published instrument flight procedure, but not an operational tower; or
d. 2 nautical miles from an airport without a published instrument flight procedure or an operational tower; or
e. 2 nautical miles from a heliport with a published instrument flight procedure.
f. Furthermore, for the correct understanding of the applied Air Risk Class assessment, knowledge of the following definitions is paramount:

Air Risk Class (ARC):

The ARC is a qualitative classification of the rate at which a UAS would encounter a manned aircraft in

typical generalised civil airspace. The ARC is an initial assignment of the aggregated collision risk for the airspace, before mitigations are applied. The actual collision risk of a specific local operational volume could be much different and can be addressed with the application of strategic mitigations to reduce the ARC.
The initial ARC is a generalised qualitative classification of the rate at which a UAS would encounter a manned aircraft in the operational volume. A residual ARC is a qualitative classification of a UAS operational collision risk in an operational volume after all strategic mitigations are applied.

Airspace Encounter Category (AEC):
The SORA used expertise from subject matter experts to rate the airspace encounter category (AEC) and the variables that influence the encounter rates (i.e., proximity, geometry, and dynamics). The variables are not interdependent, nor do they influence the encounter outcome in the same manner. The SORA only allows the manipulation of one of the variables: the proximity, i.e., the aircraft density.
Hence, lowering the aircraft density of an AEC airspace does not equate to a direct and equal lowering of the ARC risk level. There is no direct correlation between an individual AEC variable and the ARC collision risk levels.

Very Low Level Airspace (VLL):
In general, manned aircraft do not use very low level (VLL) airspace (< 400ft), as it is below the minimum safe height to perform an emergency procedure, 'unless at such a height as will permit, in the event of an emergency arising, a landing to be made without undue hazard to persons or property on the surface' (Ref. point SERA.3105 of the SERA Regulation). Subject to permission from the competent authority, special flights may be granted permission to use this airspace. Every aircraft will cross VLL airspace in an airport environment for take-off and landing.

3.2.2 The SORA process - EASA AMC1 to article 11 (EU)2019/947

The SORA provides a methodology (Figure 2) to guide both the UAS operator and the competent authority in determining whether a UAS operation can be conducted in a safe manner. The SORA methodology provides a logical process to analyse the proposed Concept of Operations (ConOps) and establish an adequate level of confidence that the operation(s) can be conducted with an acceptable level of risk.

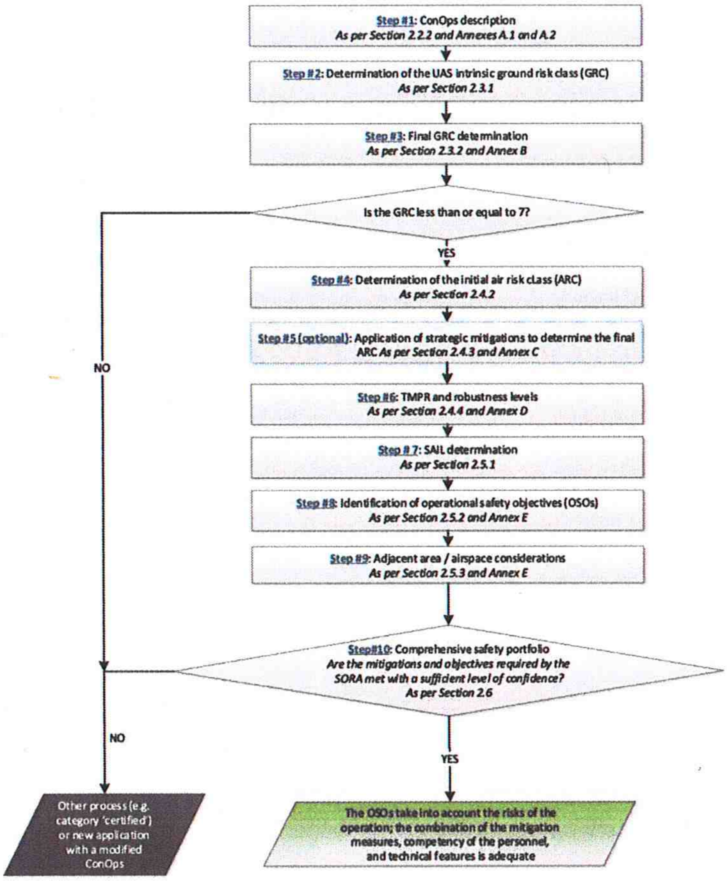

Figure 2 SORA methodology

As mentioned above, only the Air Risk Class determination and mitigation (Step #4 - #6) is applied in this safety risk assessment.

3.2.3 Determination of the Initial Air Riks Class (ARC)

As seen in Figure 3 below, the airspace is categorised into 12 aggregated collision risk categories. These categories were characterised by the altitude, controlled versus uncontrolled airspace, airport/heliport versus non-airport/non-heliport environments, airspace over urban versus rural environments, and lastly atypical (e.g., segregated) versus typical airspace. To assign the proper initial Air Risk Class (ARC) for the type of UAS operation(s), the decision tree should be used.

ARC A is generally defined as airspace where the risk of a collision between a UAS and a manned aircraft is acceptable without the addition of any tactical mitigation. ARC B, ARC C, ARC D generally define volumes of airspace with increasing risk of a collision between a UAS and a manned aircraft.

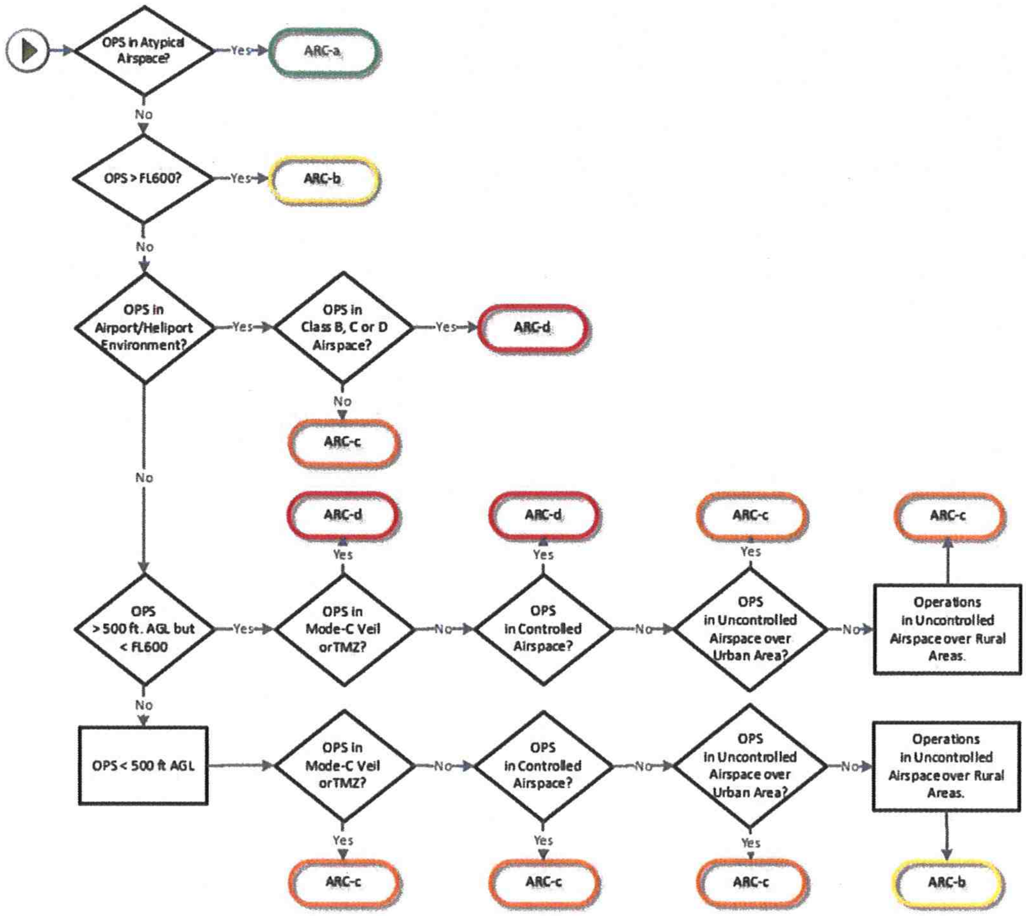

Figure 3 Flowchart ARC determination

The corresponding initial Airspace Encounter Category (AEC, rated from 1 to 12, with 12 being a very high encounter category and 1 being very low encounter category), initial Generalised Density Rating (GDR, rated from 5 to 1, with 5 being very high density, and 1 being very low density) for the initial ARC can be found in Table 1 below.

Operational environment, AEC and ARC			
Operations in:	**Initial generalised density rating**	**Corresponding AEC**	**Initial ARC**
Airport/heliport environment			
OPS in an airport/heliport environment in class B, C or D airspace	5	AEC 1	ARC-d
OPS in an airport/heliport environment in class E airspace or in class F or G	3	AEC 6	ARC-c
Operations above 400 ft AGL but below flight level 600			
OPS > 400 ft AGL but < FL 600 in a Mode-S Veil or transponder mandatory zone (TMZ)	5	AEC 2	ARC-d
OPS > 400 ft AGL but < FL 600 in controlled airspace	5	AEC 3	ARC-d
OPS > 400 ft AGL but < FL 600 in uncontrolled airspace over an urban area	3	AEC 4	ARC-c
OPS > 400 ft AGL but < FL 600 in uncontrolled airspace over a rural area	2	AEC 5	ARC-c
Operations below 400 ft AGL			
OPS < 400 ft AGL in a Mode-S Veil or TMZ	3	AEC 7	ARC-c
OPS < 400 ft AGL in controlled airspace	3	AEC 8	ARC-c
OPS < 400 ft AGL in uncontrolled airspace over an urban area	2	AEC 9	ARC-c
OPS < 400 ft AGL in uncontrolled airspace over a rural area	1	AEC 10	ARC-b
Operations above flight level 600			
OPS > FL 600	1	AEC 11	ARC-b
Operations in atypical or segregated airspace			
OPS in atypical/segregated airspace	1	AEC 12	ARC-a

Table 1

Conclusion

Based upon expert judgement and the definitions provided above the following initial ARC, AEC and Density Rating (DR) have been assigned to:

- Zone 1: ARC D, AEC 1, GDR 5
- Zone 2 A: ARC D, AEC 1, GDR 5
- Zone 2 B: ARC D, AEC 1, GDR 5
- Zone 3: ARC C, AEC 8, GDR 3
- Zone 4: ARC D, AEC 3, GDR 5

3.2.4 Lowering the Initial Air Risk Class

The ARC is a qualitative classification of the rate at which a UAS would encounter a manned aircraft in typical generalised civil airspace. The ARC is an initial assignment of the aggregated collision risk for the airspace, before mitigations are applied. The actual collision risk of a specific local operational volume could be much different and can be addressed with the application of strategic mitigations to reduce the ARC.

The SORA provides a two-step method to reduce the air risk by operational mitigation. The first step is to determine the initial ARC by using the potential air risk encounter rate based on known airspace densities. The second step is to reduce the initial risk through UAS operator-provided evidence that demonstrates that the intended operation is more indicative of another airspace volume and an encounter rate that corresponds to a lower risk classification (ARC); hence, reducing the initial ARC to a residual ARC.

Tactical mitigations are applied to mitigate any residual risk of a mid-air collision that is needed to achieve the applicable airspace safety objective. Tactical mitigations will take the form of either 'see and avoid' (i.e., operations under (E)VLOS), or they may require a system which provides an alternate means of achieving the applicable airspace safety objective (operation using a DAA, or multiple DAA systems).

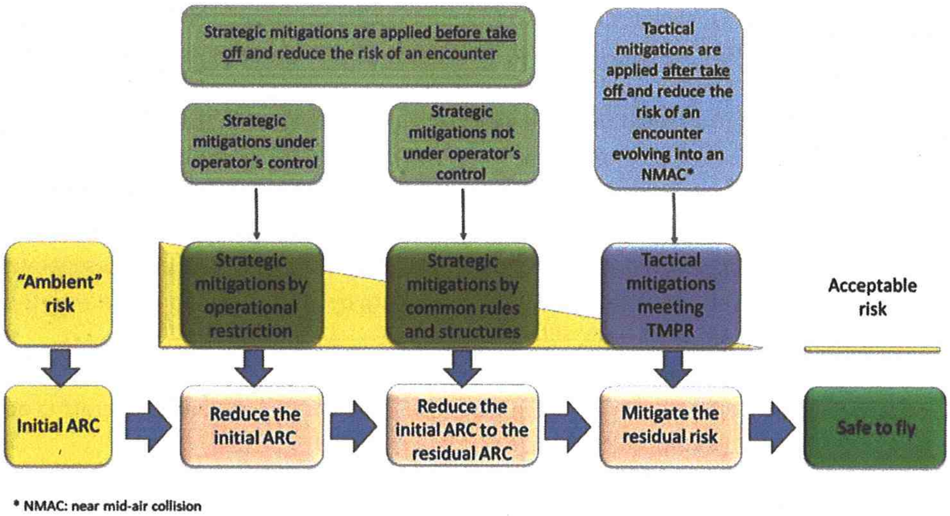

Figure 4 Flowchart ARC mitigation

Application of strategic mitigations

Strategic mitigation consists of procedures and operational restrictions intended to reduce the UAS encounter rates or the time of exposure, prior to take-off. Strategic mitigations are further divided into

a. mitigations by operational restrictions which are mitigations that are controlled by the UAS operator; and

b. mitigations by common structures and rules which are mitigations which cannot be controlled by the UAS operator.

Operational restrictions

Operational restrictions are the primary means that a UAS operator can apply to reduce the risk of collision using strategic mitigation(s). The most common mitigations by operational restriction are:

a. mitigation(s) that bound the geographical volume in which the UAS operates (e.g., certain boundaries or airspace volumes); and

b. mitigation(s) that bound the operational time frame (e.g., restricted to certain times of day, such as flying only at night).

In addition to the above, another approach to limit exposure to risk is to limit the exposure time. This is called 'mitigation by exposure'

Common structures and rules

The SORA does not allow the initial ARC to be lowered through strategic mitigation by common structures and rules for all operations in AEC 1, 2, 3, 4, 5, and 11. Similarly, the SORA does not allow for lowering the initial ARC through strategic mitigation by using common structures and rules for all operations in AEC 10.

The maximum amount of ARC reduction through strategic mitigation by using common structures and rules is by one ARC level.

The SORA does allow for lowering the initial ARC through strategic mitigation by structures and rules for all operations below 400 ft AGL within VLL airspace (AECs 7, 8, 9 and 10).

To claim an ARC reduction through strategic mitigations by structures and rules, the UAS operator should show the following:

a. the UA is equipped with an electronic cooperative system, and navigation and anti- collision lighting;
b. a procedure has been implemented to verify the presence of other traffic during the UAS flight operation (e.g., checking other aircraft's filed flight plans, NOTAMs, etc.);
c. a procedure has been implemented to notify other airspace users of the planned UAS operation (e.g., filing of the UAS flight plan, applying for a NOTAM from the service provider for UAS5 operations, etc.);
d. permission has been obtained from the airspace owner to operate in that airspace (if applicable);
e. compliance with the airspace UAS flight rules, the UAS Regulation, and the policies, etc. applicable to the UAS operational volume and with which all/most aircraft are required to comply (these flight rules, the UAS Regulation, and policies are aimed primarily at UAS operations in VLL airspace);
f. a UAS airspace structure (e.g., U-space) exists in VLL airspace to help keep UAS separated from manned aircraft. This structure must be complied with by all UAS in accordance with the EU or national regulations;
g. a UAS airspace procedural separation service has been implemented for VLL airspace. The use of this service must be mandatory for all UAS to keep UAS separated from manned aircraft in accordance with the SERA Regulation; and
h. all UAS operators can directly communicate with the air traffic controller or flight information services directly or through a U-space service provider in accordance with the SERA Regulation (EU).

After determining the initial Air Risk Class, Airspace Encounter Category (AEC) and Generalised Density Rating (GDR), the table below can be used to lower the initial ARC. Column C shows the relative density ratings that a UAS operator should demonstrate to the competent authority to argue and justify that the actual local air density rating of the operational area is lower than the rating associated with the initial AEC (Column A). If this can be shown and accepted by the competent authority, then the new lower ARC level as shown in column D may be applicable.

The density rating of manned aircraft, assessed on a scale of 1 to 5, with 1 representing a very low density and 5 representing a very high density.				
Column	A	B	C	D
AEC	Initial generalised density rating for the environment	Initial ARC	If the local density can be demonstrated to be similar to:	New lowered (residual) ARC
AEC 1 or; AEC 2	5	ARC-d	4 or 3	ARC-c
			2 or 1 Note 1	ARC-b
AEC 3	4	ARC-d	3 or 2	ARC-c
			1 Note 1	ARC-b
AEC 4	3	ARC-c	1 Note 1	ARC-b
AEC 5	2	ARC-c	1 Note 1	ARC-b
AEC 6 or; AEC 7 or; AEC 8	3	ARC-c	1 Note 1	ARC-b
AEC 9	2	ARC-c	1 Note 1	ARC-b
Note 1: The reference environment for assessing density is AEC 10 (OPS < 400 ft AGL over rural areas).				
AEC10 and AEC 11 are not included in this table, as any ARC reduction would result in ARC-a. A UAS operator claiming a reduction to ARC-a should demonstrate that all the requirements that define atypical or segregated airspace have been met.				

Table 2

Conclusion

Based upon expert judgement on the current available strategic mitigations available for UAS operations in Dutch civil CTR and the proposed (lateral) zones and associated (vertical) height limitations, the following residual GDR and ARC have been assigned to:

- Zone 1: GDR 1, ARC B
  - Common Rules: separation by means of ATC service and visibility requirements for manned aircraft (detectable trough ADS-B In/ web based real time aircraft tracking service) + coordination (GoDrone) and communication (RT/telephone) of flights with ATC by unmanned aircraft + visibility (lights) for unmanned aircraft
  - Common Structures: separation of both IFR/VFR traffic by means of routes for manned aircraft and zoning in accordance with ED-269 for unmanned aircraft
  - Additional Safety Case* by the UAS operator approved by the ANSP and Airport

- Zone 2 A: GDR 1, ARC A
  - Operational Restriction by Geography: avoid low-flying traffic, including exemption holders, by means of height limitation (zoning in accordance with ED-269) for unmanned aircraft

- Zone 2 B: GDR 1, ARC B
  - Operational Restriction by Geography: avoid low-flying traffic, excluding exemption holders, by means of height limitation (zoning in accordance with ED-269) for unmanned aircraft
  - Common Rules: separation by means of ATC service and visibility requirements for manned aircraft (detectable trough ADS-B In/ web based real time aircraft tracking service) + coordination (GoDrone) and communication (RT/telephone) of flights with ATC by unmanned aircraft + visibility (lights) for unmanned aircraft
  - Common Structures: separation of both IFR/VFR traffic by means of routes for manned aircraft

- Zone 3: GDR 1, ARC B/A
  - Operational Restriction by Geography: avoid low-flying traffic, excluding exemption holders, by means of height limitation (zoning in accordance with ED-269) for unmanned aircraft
  - Common Structures: separation of both IFR/VFR traffic by means of routes for manned aircraft

  Note ARC A: if Zone 3 could be assigned ARC A through a quantitative substantiation (e.g., radar data of UAS operations below 500ft), this would *more easily* enable BVLOS operations without LVNL providing services and having a responsibility for UAS operations in this zone.

- Zone 4: GDR 3, ARC C
  - Common Rules: separation by means of ATC service and visibility requirements for manned aircraft (detectable trough ADS-B In/ web based real time aircraft tracking service) + coordination (GoDrone) and communication (RT/telephone) of flights with ATC by unmanned aircraft + visibility (lights) for unmanned aircraft
  - Common Structures: separation of both IFR/VFR traffic by means of routes for manned aircraft and zoning in accordance with ED-269 for unmanned aircraft
  - Additional Safety Case* by the UAS operator approved by the ANSP

* The strategic mitigation reduction case should be modelled after a safety case. The size and complexity of the strategic mitigation reduction depends entirely on what the UAS operator is trying to do, and where/when they want to do it. The strategic mitigation case as a safety case has two advantages. Firstly, it provides the UAS operator with a structured approach to describe and capture the operation, the hazards identified, the risk analysed, and the threat(s) mitigated. Secondly, it provides a safety case structure that a competent authority is familiar with, which, in turn, helps the competent authority to

understand the UAS operator's intended operation and their reasoning as to why a reduction in the ARC can be safely justified.

3.2.5 Mitigating the Residual Air Risk through Tactical Mitigation Performance Requirements (TMPR)

A tactical mitigation is a mitigation applied after take-off, and for the air risk model, it takes the form of a 'mitigating feedback loop'. This feedback loop is dynamic in that it reduces the rate of collision by modifying the geometry and dynamics of the aircraft in conflict, based on real-time aircraft conflict information.

SORA tactical mitigations are applied to cover the gap between the residual risk of an encounter (the residual ARC) and the airspace safety objectives. The residual risk is the remaining collision risk after all strategic mitigations are applied.

There are two classifications of tactical mitigations within the SORA, namely:

a. (E)VLOS, whereby a pilot and/or observer uses human vision to detect aircraft and take action to remain well clear from and avoid collisions with other aircraft.
b. BVLOS, whereby an alternate means of mitigation to human vision, as in machine or machine assistance, is applied to remain well clear from and avoid collisions with other aircraft (e.g., ATC separation services, TCAS, DAA, U-space, etc.).

EVLOS:

EVLOS is considered to be an acceptable tactical mitigation for collision risk for all ARC levels. Notwithstanding the above, the UAS operator is advised to consider additional means to increase situational awareness with regard to air traffic operating in the vicinity of the operational volume.

BVLOS:

UAS operating at very low levels (e.g., 400 ft AGL and below) may technically comply with the IFR rules, but the IFR infrastructure was not designed with that airspace in mind; therefore, mitigations for this airspace would be derived, and highly impractical and inefficient. When operating BVLOS, a UAS cannot comply with VFR.

Given the above, for the purposes of this risk assessment, it is assumed that the competent authority will address these shortcomings. All aircraft must adhere to specific flight rules to mitigate the collision risk, in accordance with Regulation (EU) No 923/20122 (the standardised European rules of the air (SERA) Regulation). The implementation of procedures and guidelines appropriate to the airspace structure reduces the collision risk for all aircraft. For instance, there are equipment requirements established for the airspace requested and requirements associated with day-night operations, pilot training, airworthiness, lighting requirements, altimetry requirements, airspace restrictions, altitude restrictions, etc. These rules must still be addressed by the competent authority.

Since (E)VLOS has operational limitations, there was a concerted effort to find an alternate means of compliance with the human 'see and avoid' requirements. This alternate means of mitigation is loosely described as 'detect and avoid (DAA)'. DAA can be achieved in several ways, e.g., through ground-based DAA systems, air-based DAA systems, or some combination of the two.

TMPR provides tactical mitigations to assist the pilot in detecting and avoiding traffic under BVLOS conditions. The TMPR is the amount of tactical mitigation required to further mitigate the risks that could not be mitigated through strategic mitigation (the residual risk). The amount of residual risk is dependent on the ARC. Hence, the higher the ARC, the greater the residual risk, and the greater the TMPR.

Since the TMPR is the total performance required by all tactical mitigation means, tactical mitigations may be combined. When combining multiple tactical mitigations, it is important to recognise that the mitigation means may interact with each other, depending on the level of interdependency. This may negatively affect the effectiveness of the overall mitigation. Care should be exercised not to underestimate the negative effects of interactions between mitigation systems. Regardless of whether mitigations or systems are dependent or independent, when they act on the same event, unintended consequences may occur.

Conclusion
Based upon expert judgement on the current available tactical mitigations available for UAS operations in Dutch civil CTR, the following tactical mitigations performance requirements (TMPR) have been assigned to:

- Zone 1:
  - (E)VLOS: See & Avoid
  - BVLOS: ADS-B In/web based real time aircraft tracking service + Geofencing + RT + NOTAM + Deconfliction Scheme + Latency Checks + Descend > 1,6 m/s
- Zone 2 A:
  - (E)VLOS: See & Avoid
  - BVLOS: No TMPR
- Zone 2 B:
  - (E)VLOS: See & Avoid
  - BVLOS: ADS-B In/web based real time aircraft tracking service + Geofencing + RT + NOTAM + Deconfliction Scheme + Latency Checks + Descend > 1,6 m/s
- Zone 3:
  - (E)VLOS: See & Avoid
  - BVLOS: ADS-B In/web based real time aircraft tracking service + monitoring of aeronautical radio communications + Geofencing + NOTAM + Deconfliction Scheme + Latency Checks + Descend > 1,6 m/s (in case of ARC B) or No TMPR (in case of ARC A)
- Zone 4:
  - (E)VLOS: See & Avoid
  - BVLOS: ADS-B In/web based real time aircraft tracking service + Geofencing + RT + NOTAM + Deconfliction Scheme + Latency Checks + Descend > 1,6 m/s of Speed > 50 kts and climb > 500ft min and turn > 3 deg/sec

3.3 Conclusions

The proposed change will reduce the ATC involvement with a significant number of UAS operations in the CTR by allowing UAS to operate conditionally in predefined and published zones within the civilian CTRs. All identified safety risks have corresponding mitigations which - if validated - result in an acceptable level of safety. These mitigating measures, including the associated considerations and assumptions should therefore be incorporated into the concept design.

The safety risk mitigating measures have been converted into the following operational conditions and limitations that should be incorporated in the operational concept.

3.3.1 UAS zones

Table 3 Overview of resulting operating conditions

Zone	Operating conditions
Zone 1 Airport including a buffer area of 2 kilometres from the airport's perimeter (GNC - 120m/400ft AGL)	Open category UAS prohibited UAS operations in this zone are controlled by ATC. Specific category UAS permitted, provided: - Extra risk analysis coordinated with ANSP and airport authority - Pre-coordination with ANSP (e.g., through GoDrone) - Tactical communication (e.g., clearances) through direct two-way communication (e.g., RT or phone) - UAS has proper lighting, ADS-B In/web based real time aircraft tracking service and NOTAM published Process and operating conditions for BVLOS flights are to be specified at a later date In case of non-standard, unscheduled low level IFR flights the responsible air traffic controller (temporarily) grounds specific category UAS In case of manned aircraft flight emergency the responsible air traffic controller (temporarily) grounds specific category UAS In case of UAS emergency (i.e., fly-away), UAS operator will inform ANSP (e.g., through phone)
Zone 2A Extends from the outer edge of zone 1 till 5km from the airport's perimeter (GND - 45m/150ft AGL)	Open category UAS prohibited Specific category UAS permitted In case of UAS emergency (i.e., fly-away), UAS operator will inform ANSP (e.g., through phone)
Zone 2B Extends from the outer edge of zone 1 till 5km from the airport's perimeter (45m/150ft - 120m/400ft AGL)	Open category UAS prohibited UAS operations in this zone are controlled by ATC. Specific category UAS permitted, provided - Pre-coordination with ANSP (e.g., through GoDrone) - Tactical communication (e.g., clearances) through direct two-way communication (e.g., RT or phone) - UAS has proper lighting, ADS-B In/web based real time aircraft tracking service Process and operating conditions for BVLOS flights are to be specified at a later date In case of non-standard, unscheduled low level IFR flights the responsible air traffic controller (temporarily) grounds specific category UAS In case of manned aircraft flight emergency the responsible air traffic controller (temporarily) grounds specific category UAS In case of UAS emergency (i.e., fly-away), UAS operator will inform ANSP (e.g., through phone)

Zone	Operating conditions
Zone 3 Extends from the outer edge of zone 2 to the CTR boundary (GND - 120m/400ft AGL)	Open category UAS permitted Specific category UAS permitted Process and operating conditions for BVLOS flights are to be specified at a later date In case of UAS emergency (i.e., fly-away), UAS operator will inform ANSP (e.g., through phone)
Zone 4 The entire CTR (above 120m/400ft AGL)	Open category UAS prohibited UAS operations in this zone are controlled by ATC. Specific category UAS permitted, provided: - Extra risk analysis coordinated with ANSP - Pre-coordination with ANSP (e.g., through GoDrone) - Tactical communication (e.g., clearances) through direct two-way communication (e.g., RT or phone) - UAS has proper lighting, ADS-B In/web based real time aircraft tracking service and NOTAM published Process and operating conditions for BVLOS flights are to be specified at a later date In case of non-standard, unscheduled low level IFR flights the responsible air traffic controller (temporarily) grounds specific category UAS In case of manned aircraft flight emergency the responsible air traffic controller (temporarily) grounds specific category UAS In case of UAS emergency (i.e., fly-away), UAS operator will inform ANSP (e.g., through phone)

3.3.2 General

Publication 1

The UAS zones and its use in the five CTRs should be published in the Aeronautical Information Publication (AIP) and should be made available in the format defined by EUROCAE in ED-269 - Minimum Operational Performance Standard for UAS Geo-Fencing to enable the publishment of these zone in digital applications (e.g., GoDrone).

A warning (text box) should be added to the relevant aeronautical charts, indicating that in the CTR UAS zones uncontrolled UAS operations may be expected.

Publication 2

UAS pilots should be warned of the effect that wake vortices may have on the controllability of the UAS and the safety risk that this may bring about.

3.4 Recommendation

In standard aviation change processes, it is essential that after the change has been realised, a safety verification is performed to ensure that the intended safety quality has been achieved. It is therefore recommended to draft a monitoring plan to prepare for a safety verification of the introduced concept of operations, demonstrating that the safety goals have been met. Would that not be the case, additional mitigating measures need to be developed and introduced to correct the identified deficiencies.

ANNEX A- SAFETY RISK MATRIX[4]

The safety acceptability levels are based on the combination of the probability of a hazard or occurrence, and the severity of the effects when the hazard would occur. The probability and severity together make up the well-known safety risk matrix.

Within the risk matrix four levels of safety risk acceptability are defined

I. Unacceptable
Unacceptable safety risks are not allowed and should be mitigated.

II. Tolerable
Tolerable risks can be accepted under the condition that it is shown that anything reasonable has been done to make the risk as low as possible (the ALARP principle, as low as reasonably practicable).

III. Acceptable
Safety risks of acceptability category III are considered to be sufficiently mitigated, hence the green colour in the figure.

IV. Negligible
Safety risks of acceptability category III are considered to be sufficiently mitigated, hence the green colour in the figure. Category IV is introduced to allow a distinction between acceptable and negligible risks.

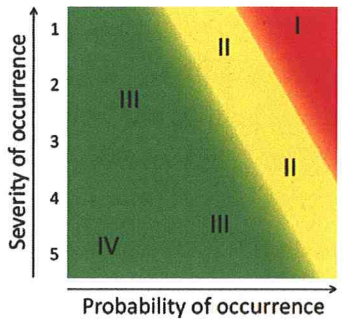

Figure 5 Safety risk matrix

Note that the as-low-as-reasonably-possible principle should also be applied to acceptable and negligible safety risks, but what is 'reasonably practicable' is less strict than for tolerable safety risks.
The safety risk matrix with the four acceptability levels is the basis for the different safety criteria that can be applied in safety assessments.

[4] LVNL Safety Criteria Framework, ORM 2019-6200, version 1.1

ANNEX B - RELEVANT SERA REGULATIONS

SERA.6001 Classification of airspaces

(a) Member States shall designate airspace in accordance with the following airspace classification and in accordance with Appendix 4:

(3) *Class C*. IFR and VFR flights are permitted. All flights are provided with air traffic control service and IFR flights are separated from other IFR flights and from VFR flights. VFR flights are separated from IFR flights and receive traffic information in respect of other VFR flights and traffic avoidance advice on request. Continuous air-ground voice communications are required for all flights. For VFR flights a speed limitation of 250 kts indicated airspeed (IAS) applies below 3 050 m (10 000 ft) AMSL, except where approved by the competent authority for aircraft types, which for technical or safety reasons, cannot maintain this speed. All flights shall be subject to ATC clearance.

(4) *Class D*. IFR and VFR flights are permitted and all flights are provided with air traffic control service. IFR flights are separated from other IFR flights, receive traffic information in respect of VFR flights and traffic avoidance advice on request. VFR flights receive traffic information in respect of all other flights and traffic avoidance advice on request. Continuous air-ground voice communications are required for all flights and a speed limitation of 250 kts IAS applies to all flights below 3 050 m (10 000 ft) AMSL, except where approved by the competent authority for aircraft types, which for technical or safety reasons, cannot maintain this speed. All flights shall be subject to ATC clearance.

GM1 SERA.6001 Classification of airspaces

GENERAL

Class B airspace is considered less restrictive than Class A airspace; Class C airspace less restrictive than Class B airspace, etc.

a. The speed limitation of 250 kt for VFR flights in airspace Classes C, D, E, F, G and for IFR flights in airspace Classes D, E, F, G is intended to facilitate visual acquisition of flights which are not separated.

b. Wherever there is a need to accommodate within a given airspace class operations compatible with a less restrictive class, the following may be used:

1. reclassification of the airspace concerned;
2. redesigning the volume of airspace concerned by defining airspace restrictions or reservations, or sub volumes of less restrictive classes of airspace (e.g., corridors).

SERA.7001 Objectives of the air traffic services

The objectives of the air traffic services shall be to:

a. prevent collisions between aircraft;
b. prevent collisions between aircraft on the manoeuvring area and obstructions on that area;
c. expedite and maintain an orderly flow of air traffic;
d. provide advice and information useful for the safe and efficient conduct of flights;
e. notify appropriate organisations regarding aircraft in need of search and rescue aid, and assist such organisations as required.

SERA.8001 Application of air traffic services

Air traffic control service shall be provided:

a. to all IFR flights in airspace Classes A, B, C, D and E;
b. to all VFR flights in airspace Classes B, C and D;
c. to all special VFR flights;
d. to all aerodrome traffic at controlled aerodromes.

SERA.8005 Operation of air traffic service

c. Except for cases of operations on parallel or near-parallel runways as in point ATS.TR.255 of Annex IV to Commission Implementing Regulation (EU) 2017/3731, or when a reduction in separation minima in the vicinity of aerodromes can be applied, separation by an ATC unit shall be obtained by at least one of the following:

    1. vertical separation, obtained by assigning different levels selected from the table of cruising levels in Appendix 3, except that the correlation of levels to track as prescribed therein shall not apply whenever otherwise indicated in appropriate aeronautical information publications or ATC clearances. The vertical separation minimum shall be a nominal 300 m (1 000 ft) up to and including FL 410 and a nominal 600 m (2 000 ft) above that level. Geometric height information shall not be used to establish vertical separation;
    2. (horizontal separation, obtained by providing:
        i. longitudinal separation, by maintaining an interval between aircraft operating along the same, converging or reciprocal tracks, expressed in time or distance; or
        ii. lateral separation, by maintaining aircraft on different routes or in different geographical areas.

SERA.8015(a) Air traffic control clearances

Clearances to VFR flights in airspace classes C and D do not imply any form of separation:

a. in Class C – between VFR flights; and
b. in Class D – between IFR and VFR flights or between VFR flights.

SERA.9001 Application of Flight information service

a. Flight information service shall be provided by the appropriate air traffic services units to all aircraft which are likely to be affected by the information and which are:
    1. provided with air traffic control service; or
    2. otherwise known to the relevant air traffic services units.

SERA.10001 Application of Alerting service

a. Alerting service shall be provided by the air traffic services units:
    1. for all aircraft provided with air traffic control service;
    2. in so far as practicable, to all other aircraft having filed a flight plan or otherwise known to the air traffic services; and
    3. to any aircraft known or believed to be the subject of unlawful interference.

ANNEX C - ICAO APPLICATION OF ANNEX 14 CRITERIA

The safety regulation for manned flight operations in the vicinity of airports differs from the generally applicable rules with regard to the minimum altitude for IFR flights (1000ft above the highest obstacle within 8km), specially for the take-off or landing.

To protect flights operating at airports, additional measures have been published to reduce the risk of collision between aircraft and obstacles on the ground in the vicinity of airports. ICAO Doc 8168 Vol II (PANS-OPS) defines protection areas associated to flight procedures, both instrument and visual, while ICAO Annex 14 (Aerodromes) specifies Obstacle Limitation Surfaces (OLS) associated to runways and airports, to limit the obstacles in the terminal airspace where flights are expected.

Starting point for the conceptual design of drone zones in civil CTRs is that manned flights and UAS operating in the designated drone zones without ATC support stay clear of IFR and VFR flights in the CTR. In general, 500ft vertical distance to IFR flights is guaranteed in the design. However, in those flight segments where aircraft operate below the general minimum altitude, 500ft vertical distance to the UASs is not always feasible. Instead of applying the 500ft standard in those cases, the drone zone design defines the drone zones in such a way that UAS operating in the drone zones concerned will not penetrate the relevant OLSs, thus assuring by design the safety of manned flights as well as UAS. Since the OLSs are generally more conservative than the PANS-OPS safety surfaces, the drone zone design considers the Annex 14 OLS criteria only.

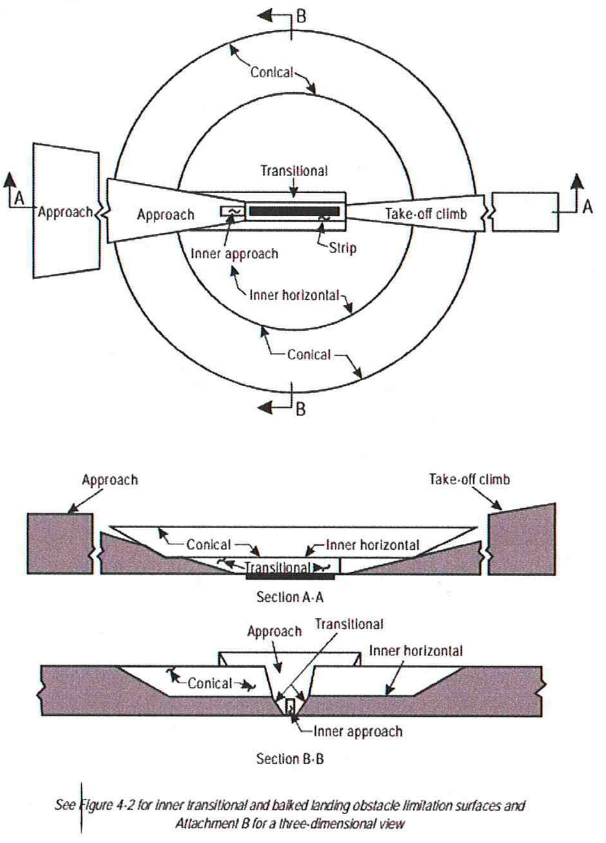

Figure 6 ICAO Annex 14 Volume I chapter 4 - obstacle limitation surfaces

When the basic concept as described in chapter 2.2 is projected onto the Annex 14 criteria, it turns out that at the inner boundary of Zone 2, the take-off surface is lower than 150ft/45m (Figure 7).

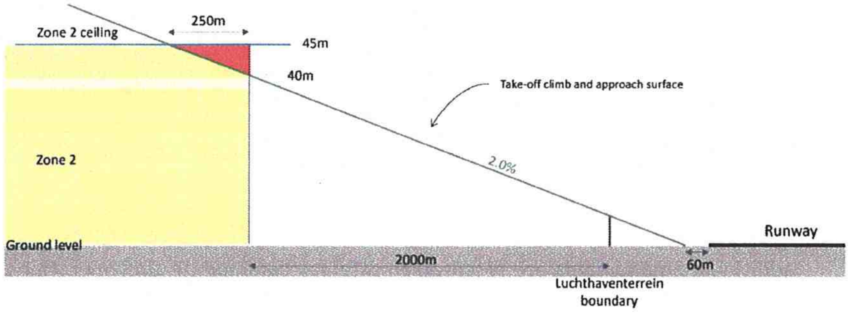

Figure 7 Conceptual OLS penetration by Zone 2

UAS operating in Zone 2 close to the airport and near the ceiling of the drone zone would penetrate the approach surface, creating a safety risk to flights departing from the airport. To prevent these OLS penetrations by UAS operations, the inner boundary of Zone 2 has been redefined beyond the 2km design principle (Figure 8) where applicable.

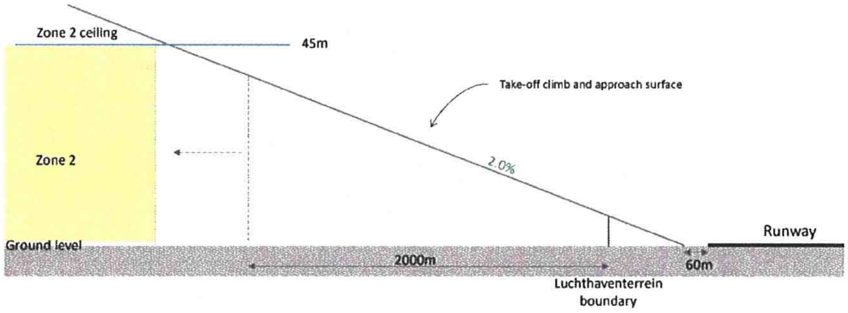

Figure 8 Relocated boundary of Zone 2, clear of the OLS

A similar situation occurs for Zone 3, where UAS may operate up to 120m AGL. In these cases, the zone definition has been amended assuring that the geographical concept definition of the zone assures operation below the relevant OLSs (see Figure 9).

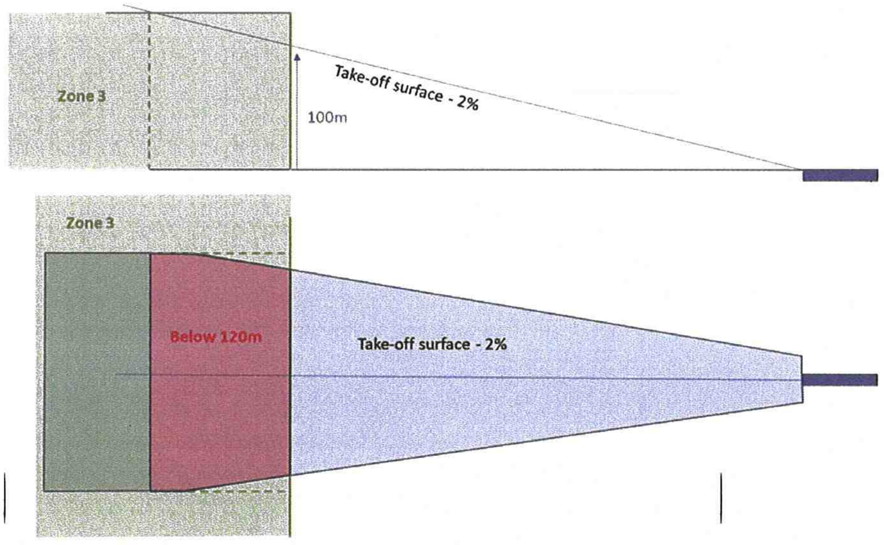

Figure 9 Relocated boundary of Zone 3, clear of the OLS

Table 4 below provides an overview of the obstacle limitation surfaces and its relevance and or processed impact on the drone zone design of the five civil CTRs.

Table 4 Overview of OLS relevance to the drone zone design

OLS	Rationale
Take-off surface	The relevant take-off surfaces have been taken into account in the drone zone designs, keeping the accommodated UAS operations clear, i.e. below the take-off surfaces.
Approach surface	The approach surface is above or equal to the take-off surface. Therefore no additional amendments are required to safely accommodate UAS operations in the drone zones as designed.
Transitional surface	The transitional surfaces connect laterally to the approach surfaces inside drone Zone 1 and therefore do not influence the drone zone design.
Inner horizontal surface	The inner horizontal surface has an overall height of 45m. It extends to 4km beyond the runway in all directions. It overlaps with Zone 1 and Zone 2. In Zone 2, UAS can operate until 45 meters. Therefore the inner horizontal surface does not influence the drone zone design.
Conical surface	The conical surface extends 2km beyond the inner horizontal surface, thus overlapping with Zones 2 and 3. It slopes outwards from 45m to 145m. In some situations, this surface remains slightly below 120m at the boundary between Zone 2 and Zone 3. Since the purpose of the conical surface is the protection of aircraft in the VFR circuit, and since the specific VFR procedures at the civil airports have been considered in the design, the limited Zone-3 penetration of the conical surface is no reason to amend the definition of Zone 3.

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