Joint Authorities for Rulemaking of Unmanned Systems

JARUS guidelines on Specific Operations Risk Assessment (SORA)

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Abstract

This document recommends a risk assessment methodology to establish a sufficient level of confidence that a specific operation can be conducted safely. It allows the evaluation of the intended concept of operation and a categorization into 6 different Specific Assurance and Integrity Levels (SAIL). It then recommends operational safety objectives to be met for each SAIL.

Keywords

SORA, SAIL, Specific, Risk

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Annex B: Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Classes	1.0
Annex C: Strategic Mitigation Collision Risk Assessment	1.0
Annex D: Tactical Mitigations Collision Risk Assessment	1.0
Annex E: Integrity and assurance levels for the Operational Safety Objectives (OSO)	1.0
Annex F: Supporting data for the Air Risk Model	In preparation
Annex G: Supporting data for the Air Risk Model	In preparation
Annex H: Unmanned Traffic Management (UTM) implications to SORA	In preparation
Annex I: Glossary	1.0
Annex J: Guidance to Regulators, ANSPs, and Other Third Parties	In preparation

1. Introduction

1.1 Preface

(a) This updated issue of the Specific Operation Risk Assessment (SORA) is the JARUS WG-6 consensus vision on how to safely create, evaluate and conduct an Unmanned Aircraft System (UAS) operation. The SORA provides a methodology to guide both the applicant and the competent authority in determining whether an operation can be conducted in a safe manner. The document shall not be used as a checklist, nor be expected to provide answers to all the challenges related to integration of the UAS in the airspace. The SORA is a tailoring guide that allows an operation to find a best fit mitigation means and hence reduce risk to an acceptable level. For this reason, it does not contain prescriptive requirements but rather safety objectives to be met at various levels of robustness commensurate with risk.

(b) The SORA is meant to inspire operators and competent authorities and highlight the benefits of a harmonized risk assessment methodology. The feedback collected from real-life operations will form the backbone of updates to the upcoming revisions of the document.

1.2 Purpose of the document

(a) The purpose of the SORA is to propose a methodology for the risk assessment to support an application for authorization to operate a UAS within the *specific*[a] category.

(b) Due to the operational differences and expanded level of risk, the specific category cannot automatically take credit for the safety and performance data demonstrated with the large number of UA operating in the open category. Therefore, the SORA provides a consistent approach to assess the additional risks associated with the expanded and new operations not covered by the open category.

(c) This methodology is proposed as an acceptable means to evaluate the risks and determine the acceptability of a proposed operation of UAS within the specific category.

(d) The SORA is not intended as a one-stop-shop for full integration of all type of drones in all classes of airspace.

(e) This methodology may be applied where the traditional approach to aircraft certification (approving the design, issuing an airworthiness approval and type certificate) may not be appropriate due to an applicant's desire to operate a UAS in a limited or restricted manner. This methodology may also support activities necessary to determine associated airworthiness requirements. This assumes that safety objectives set forth in or derived from those applicable for the Certified category, are consistent with the ones set forth or derived for the Specific category.

(f) The methodology is based on the principle of a holistic/total system safety risk-based assessment model used to evaluate the risks related to a given operation. The model considers all natures of threats associated with a specified hazard, the relevant design, and the proposed operational mitigations for a specific operation. The SORA then helps to evaluate the risks systematically and determine the boundaries required for a safe operation. This method allows the applicant to determine acceptable risk levels and to validate that those levels are complied with by the proposed operations. The competent authority may also apply this methodology to gain confidence that the operator can conduct the operation safely.

[a] This category of operations is further defined in the European Aviation Safety Agency (EASA) Opinion 01/2018.

(g) To avoid repetitive individual approvals, the competent authority may also apply the methodology to define “standard scenarios” for identified types of Concept of Operations (ConOps) with known hazards and acceptable risk mitigations.

(h) The methodology, related processes, and values proposed in this document are intended to guide the competent authorities when performing a risk assessment. The competent authorities could decide to adapt any section of this document into their regulatory framework.

1.3 Applicability

(a) The methodology presented in this document is aimed at evaluating the safety risks involved with the operation of Unmanned Aircraft System (UAS) of any class and size and type of operation (including military, experimental, R&D and prototyping). It is particularly suited, but not limited to “specific” operations for which a hazard and risk assessment is required.

(b) Safety risks associated with collisions between UA and manned aircraft are in the scope of the methodology. The risk of collision between two UA or between a UA and a UA carrying people will be addressed in future revisions of the document.

(c) In the event of mishap, the carriage of people or payloads on board the UAS (e.g. weapons) that present additional hazards are explicitly excluded from the scope of this methodology.

(d) Security aspects are excluded from the applicability of this methodology when not limited to those confined by the airworthiness of the systems (e.g. aspects relevant to the protection from unlawful electromagnetic interference.)

(e) Privacy and financial aspects are excluded from the applicability of this methodology.

(f) The SORA can be used to support waiving regulatory requirements applicable to the operation if it can be demonstrated that the operation can be conducted with an acceptable level of safety.

(g) In addition to performing a SORA, the operator must also ensure compliance to all other regulatory requirements applicable to the operation that are not necessarily addressed by the SORA.

1.4 Key concepts and definitions

A glossary providing all abbreviations and definitions related to the SORA is provided in Annex I.

1.4.1 Semantic model

(a) To facilitate effective communication of all aspects of the SORA, the methodology requires standardized use of terminology for phases of operation, procedures, and operational volumes. The semantic model shown in Figure 1, provides a consistent use of terms for all SORA users. Figure 2 provides a graphical representation of the model and a visual reference to further aid the reader in understanding the SORA terminology.

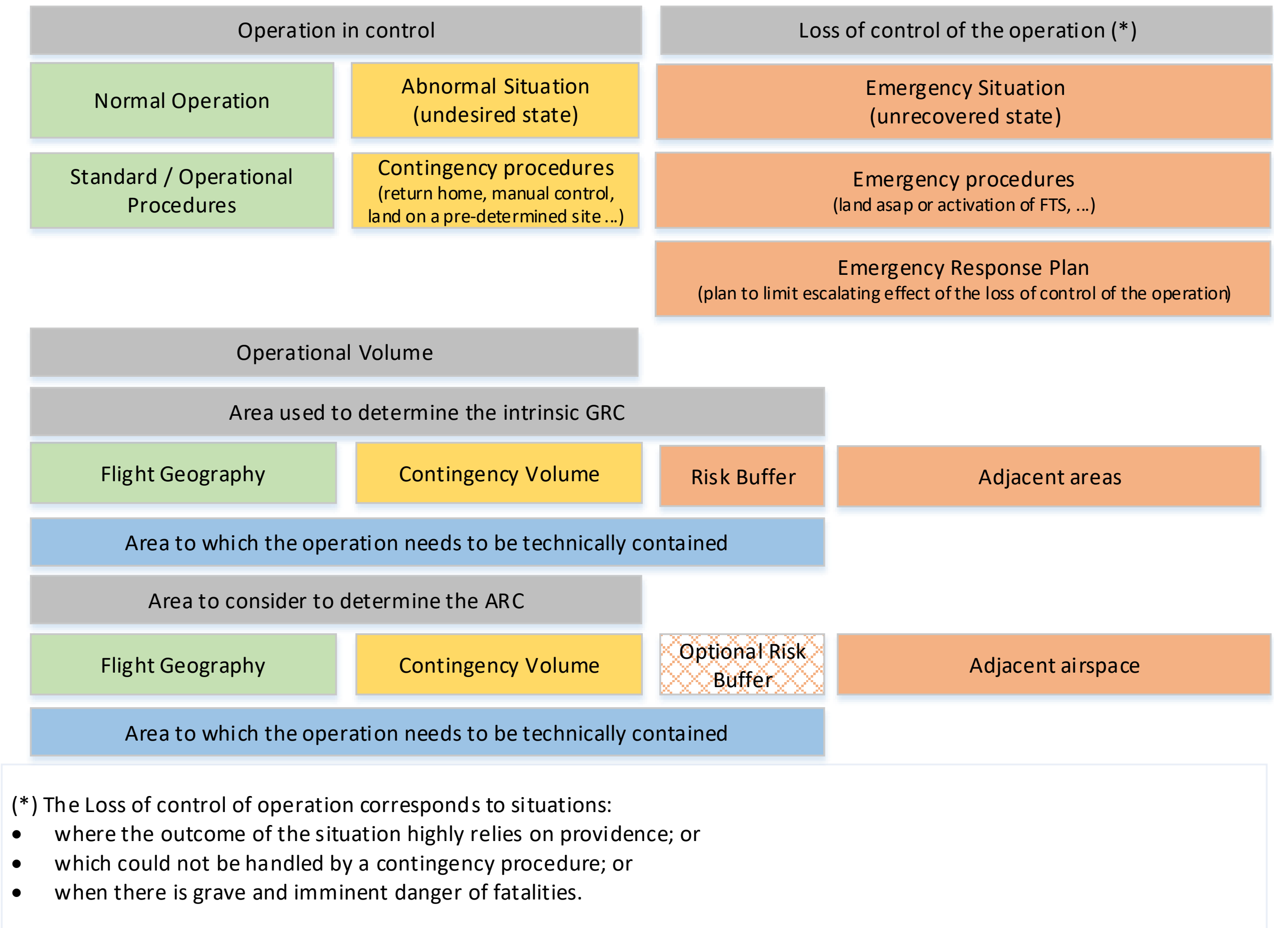

Figure 1 – SORA Semantic Model

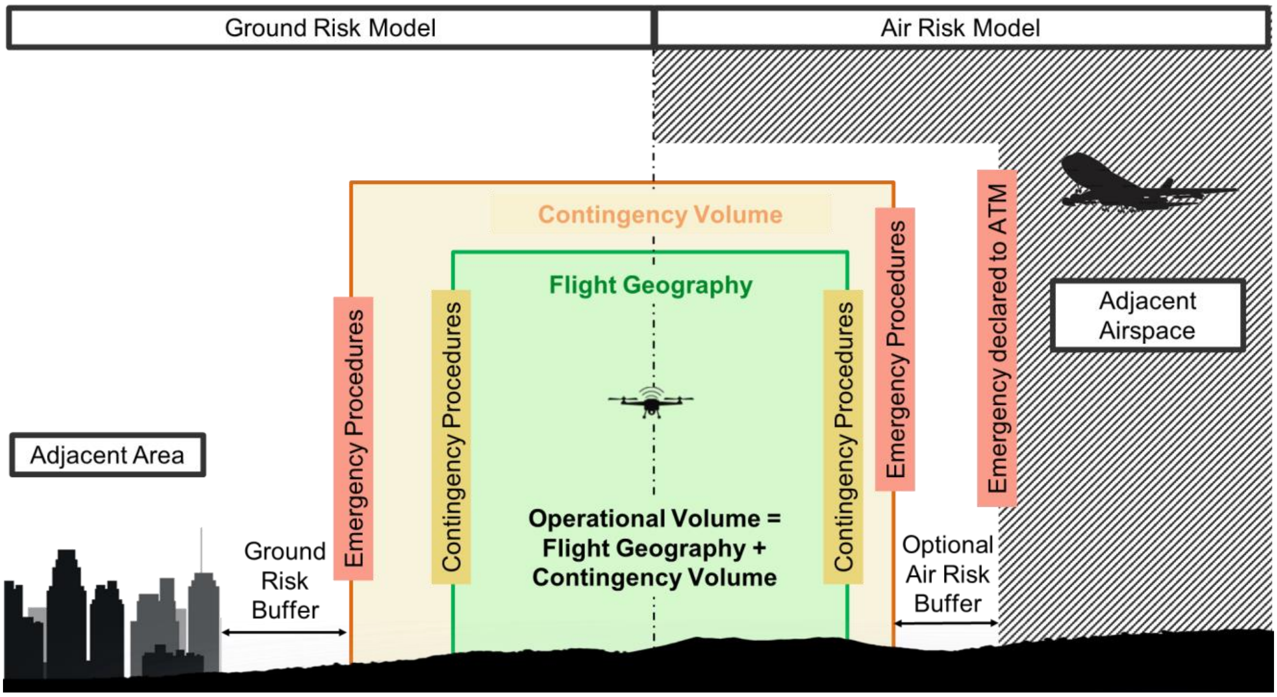

Figure 2 – Graphical Representation of SORA Semantic Model

1.4.2 Introduction to robustness

(a) To properly understand the SORA process, it is important to introduce the key concept of robustness. Any given risk mitigation or operational safety objective can be demonstrated at differing levels of robustness. The SORA proposes three different levels of robustness: Low, Medium and High, commensurate with risk.

(b) The **robustness** designation is achieved using both the **level of integrity** (i.e. safety gain) provided by each mitigation, and the **level of assurance** (i.e. method of proof) that the claimed safety gain has been achieved. These are both risk-based.

(c) The activities used to substantiate the level of integrity are detailed in the Annexes B, C, D and E. Those annexes provide either guidance material or reference industry standards and practices where applicable.

(d) General guidance for the level of assurance is provided below:

A **Low** level of assurance is where the applicant simply declares that the required level of integrity has been achieved.

A **Medium** level of assurance is one where the applicant provides supporting evidence that the required level of integrity has been achieved. This is typically achieved by means of testing (e.g. for technical mitigations) or by proof of experience (e.g. for human-related mitigations).

A **High** level of assurance is where the achieved integrity has been found acceptable by a competent third party.

(e) The specific criteria defined in the Annexes take precedence over the criteria defined in paragraph d.

(f) To accommodate national specificities that cannot and should not be standardized, the competent authorities might require different activities to substantiate the level of robustness.

(g) Table 1 provides guidance to determine the level of robustness based on the level of integrity and the level of assurance:

	Low Assurance	Medium Assurance	High Assurance
Low Integrity	Low robustness	Low robustness	Low robustness
Medium Integrity	Low robustness	Medium robustness	Medium robustness
High Integrity	Low robustness	Medium robustness	High robustness

Table 1 – Determination of Robustness level

(h) For example, if an applicant demonstrates a Medium level of Integrity with a Low level of assurance the overall robustness will be considered as Low. In other words, the robustness will always be equal to the lowest level of either integrity or assurance.

1.5 Roles and Responsibilities

(a) While performing a SORA process and assessment, several key actors might be required to interact in different phases of the process. The main actors applicable to the SORA are described in this section.

(b) Operator – The operator is responsible for safe operation of the UAS and hence the safety risk analysis. The operator must substantiate the safety of the operation by performing the specific operational and risk assessment. Supporting material for the assessment may be provided by third parties (e.g. the manufacturer of the UAS or equipment, UTM service providers, etc.). The operator obtains an operational authorization from the Competent Authority/ANSP.

(c) Applicant – The applicant is the party seeking operational approval. The applicant becomes the operator once the operation has been approved.

(d) UAS Manufacturer – For the purposes of the SORA, the UAS manufacturer is the party that designs and manufactures the UAS. The manufacturer/designer has unique design evidence (e.g. system performance, system architecture, software/hardware development documentation, test/analysis documentation, etc.) that they may choose to make available to one or many UAS operator(s) or the competent authority to help substantiate the operator's safety case. Alternatively, a potential UAS manufacturer may utilize the SORA to target design objectives for specific or generalized operations. To obtain airworthiness approval(s), these design objectives could be complemented by use of JARUS Certification Specifications (CS) or industry consensus standards if they are found acceptable by the competent authority.

(e) Component Manufacturer – The component manufacturer is the party that designs and manufactures components for use in UAS operations. The component manufacturer has unique design evidence (e.g. system performance, system architecture, software/hardware development documentation, test/analysis documentation, etc.) that they may choose to make available to one or many UAS operator(s) to substantiate a safety case.

(f) Competent Authority – The competent authority is the recognized authority for approving the safety case of UAS operations. The competent authority may accept an applicant's SORA submission in whole or in part. Through the SORA process, the applicant may need to consult with the competent authority to ensure consistent application or interpretation of individual steps. The competent authority may also have oversight of the

UAS manufacturer and component manufacturer and may approve the design and/or the manufacture of each. The Competent Authority also provides the operational approval to the operator.

(g) Air Navigation Service Provider (ANSP) – The ANSP is the designated provider of air traffic service in a specific area of operation (airspace). The ANSP assesses whether the proposed operation can be safely conducted in the particular airspace that they cover, and if so authorises the flight. Because the concurrency of multiple operations may require interaction of the airspace users, ANSPs must be consulted on any unique solutions produced by the SORA which do not conform to standard flight rules of the airspace. Please refer to Annex J for more information on ANSP roles, responsibilities, and interactions with applicants.

(h) UTM/U-Space Service Provider – UTM/U-Space Service Providers are entities that provide services to support safe and efficient use of airspace. These services may support an operator's compliance with their safety obligation and risk analysis as described in Annex H.

(i) Pilot in Command – The pilot is designated by the operator or, in case of general aviation, the aircraft owner, as being in command and charged with the safe conduct of the flight.

2. The SORA Process

2.1 Introduction to Risk

(a) Many definitions of the word “**risk**” exist in the literature. One of the easiest and most understandable definitions is provided in the SAE ARP 4754A / EUROCAE ED-79A: “the combination of the *frequency* (probability) of an *occurrence* and its associated level of *severity*”. This definition of “risk” is retained in this document.

(b) The consequence of an occurrence will be designated as a **harm** of some type.

(c) Many different categories of harm arise from any given occurrence. Various authors on this topic have collated these categories of harm as supported by literature. This document will focus on occurrences of harm (e.g. an UAS crash) that are short-lived and usually give rise to near loss of life. Chronic events (e.g. toxic emissions over a period of time), are explicitly excluded from this assessment. The categories of harm in this document are the potential for:

- Fatal injuries to third parties on the ground
- Fatal injuries to third parties in the air
- Damage to critical infrastructure

(d) It is acknowledged that the competent authorities when appropriate, may consider additional categories of harm (e.g. disruption of a community, environmental damage, financial loss, etc.) This methodology could be used for those categories of harm as well.

(e) Several studies have shown that the amount of energy needed to cause fatal injuries in the case of a direct hit, are extremely low (i.e. in the region of few dozen Joules.) The energy levels of operations addressed within this document are likely to be significantly higher and therefore the retained harm is the potential for fatal injuries. By application of the methodology, the applicant has the opportunity to claim lower lethality either on a case by case basis, or systematically if allowed by the competent authorities (e.g. open category).

(f) Fatal injury is a well-defined condition and, in most countries, known by the authorities. Therefore, the risk of under-reporting fatalities is almost non-existent. The quantification of the associated risk of fatality is straightforward. The usual means to measure fatalities are by the number of deaths within a particular time interval (e.g. fatal accident rate per million flying hours), or the number of deaths for a specified circumstance (e.g. fatal accident rate per number of take-offs).

(g) Damage to critical infrastructure is a more complex condition and different countries may have differing sensitivities to this harm. Therefore the quantification of the associated risks may be difficult and subject to national specificities.

2.2 SORA Process Outline

(a) The SORA methodology provides a logical process to analyse the proposed ConOps and establish an adequate level of confidence that the operation can be conducted with an acceptable level of risk. There are ten steps supporting the SORA methodology and each of these steps is described in the following paragraphs and further detailed, when necessary, in the relevant annexes.

(b) The SORA focuses on the assessment of ground and air risk. In addition to air and ground risks, an additional risk assessment of critical infrastructure should also be performed. This should be done in cooperation with the organization responsible for the infrastructure, as they are most knowledgeable of those threats. Figure three outlines of the ten steps of the risk model while figure 4 provides an overall understanding of how to arrive at an Air

Risk Class (ARC) for a given operation.

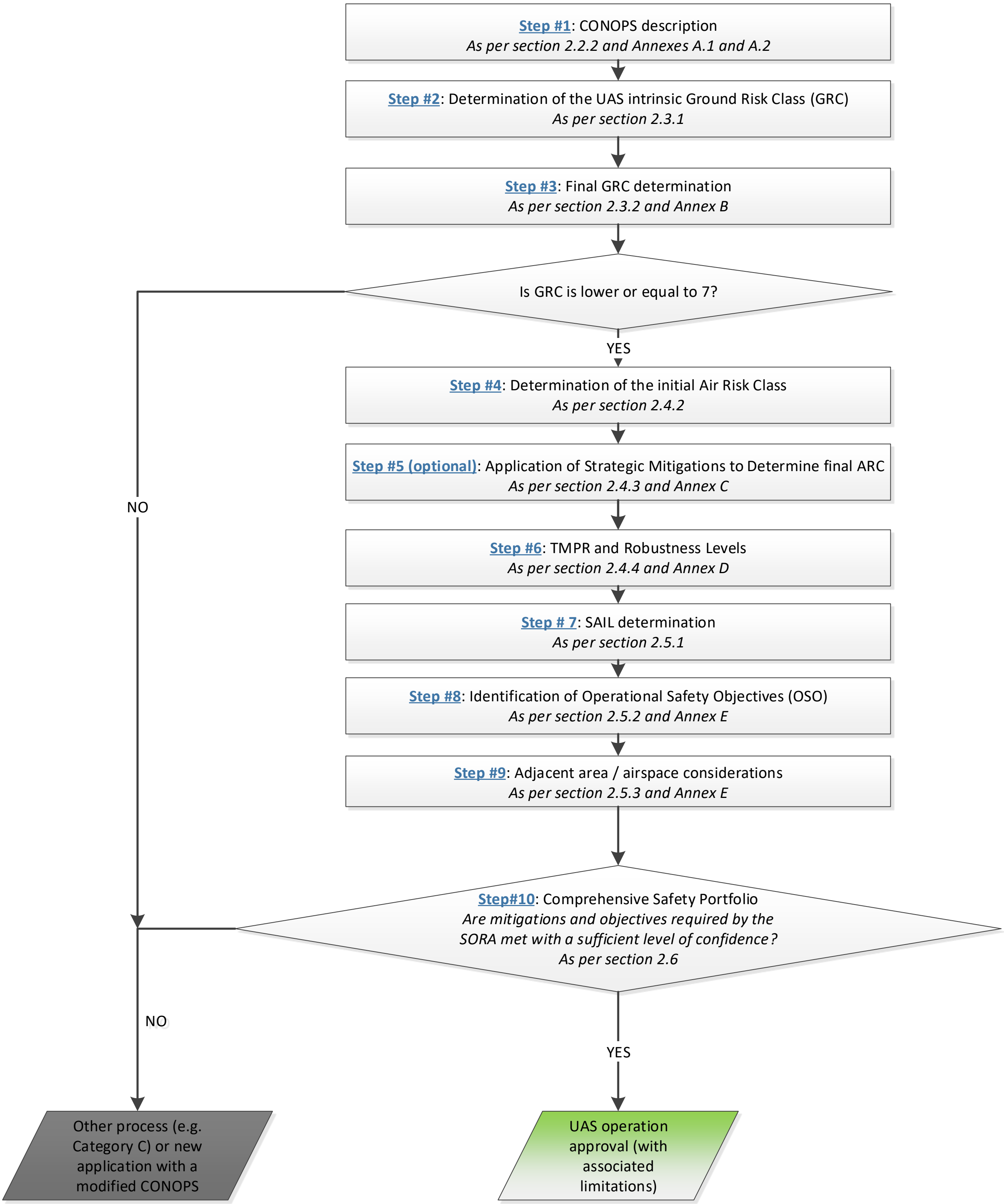

Figure 3 – The SORA process

Note: If operations are conducted across different environments, some steps may need to be repeated for each particular environment.

2.2.1 Pre-application Evaluation

(a) Before starting the SORA process, the applicant should verify that the proposed operation is feasible (i.e. not subject to specific exclusions from the competent authority or subject to a standard scenario.) Things to verify before beginning the SORA process are:

- If the operation falls under the “open” category
- If the operation is covered by a “standard scenario” recognized by the competent authority
- If the operation falls under the “certified” category
- If the operation is subject to specific NO-GO from competent authority
- If the competent authority has determined that the UAS is “harmless” for the ground risk.

If none of the above cases applies, the SORA process should be applied.

2.2.2 Step #1 – ConOps Description

(a) The first step of the SORA requires the applicant to collect and provide the relevant technical, operational and system information needed to assess the risk associated with the intended operation of the UAS. Annex A of this document provides a detailed framework for data collection and presentation. The ConOps description is the foundation for all other activities and should be as accurate and detailed as possible. The ConOps should not only describe the operation, but also provide insight into the operator’s operational safety culture. It should also include how and when to interact with ANSP (refer to Annex J). Therefore, when defining the ConOps the operator should give due consideration to all steps, mitigations and operational safety objectives provided in Figures 3 and 4.

(b) Developing the ConOps can be an iterative process; therefore as the SORA process is applied, additional mitigations and limitations may be identified, requiring additional associated technical details, procedures, and other information be provided/updated in the ConOps. This should culminate with a comprehensive ConOps that fully and accurately describes the proposed operation as envisioned.

2.3 The Ground Risk Process

2.3.1 Step #2 – Determination of the intrinsic UAS Ground Risk Class (GRC)

(a) The intrinsic UAS ground risk relates to the risk of a person being struck by the UAS (in the case of loss of UAS control with a reasonable assumption of safety.)

(b) To establish the intrinsic GRC, the applicant needs the max UA characteristic dimension (e.g. wingspan for fixed wing, blade diameter for rotorcraft, max. dimension for multi-copters, etc.) and the knowledge of the intended operational scenario.

(c) The applicant needs to have defined the area at risk when conducting the operation including:

- The operational volume which is composed of the flight geography and the contingency volume. To determine the operational volume the applicant should consider the position keeping capabilities of the UAS in 4D space (latitude, longitude, height and time). In particular the accuracy of the navigation solution, the flight technical error of the UAS and the path definition error (e.g. map error) and latencies should be considered and addressed in this determination;

- Whether the area is a controlled ground area or not;
- The associated ground risk buffer with at least a 1 to 1 rule[b];

(d) Table 2 illustrates the GRC used in the Intrinsic Ground Risk Classes (GRC) Determination. The GRC is found at the intersection of the applicable operational scenario and max UA characteristic dimension that drives the UAS lethal area. In case of a mismatch between the Max UAS characteristic dimension and the typical kinetic energy expected, the applicant should provide substantiation for the chosen column.

Intrinsic UAS Ground Risk Class				
Max UAS characteristics dimension	1 m / approx. 3ft	3 m / approx. 10ft	8 m / approx. 25ft	>8 m / approx. 25ft
Typical kinetic energy expected	*< 700 J (approx. 529 Ft Lb)*	*< 34 KJ (approx. 25000 Ft Lb)*	*< 1084 KJ (approx. 800000 Ft Lb)*	*> 1084 KJ (approx. 800000 Ft Lb)*
Operational scenarios				
VLOS/BVLOS over controlled ground area	1	2	3	4
VLOS in sparsely populated environment	2	3	4	5
BVLOS in sparsely populated environment	3	4	5	6
VLOS in populated environment	4	5	6	8
BVLOS in populated environment	5	6	8	10
VLOS over gathering of people	7			
BVLOS over gathering of people	8			

Table 2 – Intrinsic Ground Risk Classes (GRC) Determination

(e) The operational scenarios described attempt to provide discrete categorizations of operations with increasing number of **people at risk**.

(f) A detailed mathematical model to substantiate this approach is provided in Annex F.

(g) EVLOS[c] operations are to be considered as BVLOS for the GRC determination.

(h) A controlled ground area is defined as the intended UAS operational area that only involves active participants (if any)[d]. Controlled ground areas are a way to strategically mitigate the risk on ground (similar to flying in segregated airspace); the assurance that there will be non-active participants in the area of operation is under full responsibility of the operator.

(i) An operation occurring in a populated environment cannot be intrinsically classified as sparsely populated even in cases where the footprint of the operation is completely within special risk areas (e.g. rivers, railways, industrial estates). The applicant can make the

[b] *If the UA is planned to operate at 150m altitude, the ground risk buffer should at least be 150m.*

[c] EVLOS - An Unmanned Aircraft System (UAS) operation whereby the Pilot in Command (PIC) maintains an uninterrupted situational awareness of the airspace in which the UAS operation is being conducted via visual airspace surveillance through one or more human observers, possibly aided by technology means. The PIC has a direct control of the UAS at all time.

[d] Active participants are those persons directly involved with the operation of the UAS or fully aware that the UAS operation is being conducted near them. Active participants are fully aware of the risks involved with the UAS operation and have accepted these risks. Active participants are informed on and able to follow relevant effective emergency procedures and/or contingency plans.

claim for lower density and/or shelter with Step #3 of the SORA process.

(j) Operations that do not have a corresponding GRC (i.e. grey cells on the table) are not currently supported by the SORA methodology.

(k) When evaluating the typical kinetic energy expected for a given operation, the applicant should generally use airspeed, in particular V_{cruise} for fixed-wing aircraft and the terminal velocity for other aircraft. Specific designs (e.g. gyrocopters) might need additional considerations. Guidance useful in determining the terminal velocity can be found at https://www.grc.nasa.gov/WWW/K-12/airplane/termv.html

(l) The nominal size of the crash area for most UAS can be anticipated by considering both the size and energy used in the ground risk determination. There are certain cases or design aspects that are non-typical and will have a significant effect on the lethal area of the UAS such as fuel, high-energy rotors/props, frangibility, material, etc. These may not have been considered in the ground risk class determination table. These considerations may lead to a decrease/increase in GRC. The use of industry standards or dedicated research might provide a simplified path for this assessment.

2.3.2 Step #3 – Final GRC Determination

(a) The intrinsic risk of a person being struck by the UAS (in case of loss of control of the operation) can be controlled and reduced by means of mitigations.

(b) The mitigations used to modify the intrinsic GRC have a direct effect on the safety objectives associated with a particular operation, and therefore important to ensure their robustness. This has particular relevance for technical mitigations associated with ground risk (e.g. emergency parachute).

(c) The Final GRC determination (step three) is based on the availability of these mitigations to the operation. Table 3 provides a list of potential mitigations and the associated relative correction factor. A positive number denotes an increase of the GRC, while a negative number results in a decrease of the GRC. All mitigations must be applied in numeric sequence to perform the assessment. Annex B provides additional details on how to estimate the robustness of each mitigation. Competent authorities may define additional mitigations and the relative correction factors.

		Robustness		
Mitigation Sequence	**Mitigations for ground risk**	Low/None	Medium	High
1	M1 - Strategic mitigations for ground risk[e]	**0: None** **-1: Low**	**-2**	**-4**
2	M2 - Effects of ground impact are reduced[f]	**0**	**-1**	**-2**
3	M3 - An Emergency Response Plan (ERP) is in place, operator validated and effective	**1**	**0**	**-1**

Table 3 – Mitigations for Final GRC determination

(d) When applying mitigation M1, the GRC cannot be reduced to a value lower than the lowest value in the applicable column in Table 2. This is because it is not possible to reduce the number of people at risk below that of a controlled area.

[e] This mitigation is meant as a means to reduce the number of people at risk.

[f] This mitigation is meant as a means to reduce the energy absorbed by the people of the ground upon impact.

(e) For example, in the case of a 2.5m UAS (second column in Table 2) flying in VLOS over sparsely populated area, the intrinsic GRC is 3. Upon analysis of the ConOps the applicant claims to reduce the ground risk by first applying M1 at Medium Robustness (a -2 GRC reduction). In this case, the result of applying M1 is a GRC of 2, because the GRC cannot be reduced any lower than the lowest value for that column. The applicant then applies M2 using a parachute system resulting in a further reduction of -1 (i.e. GRC 1). Finally, M3 (the ERP) has been developed to Medium robustness with no further reduction as per Table 3.

(f) The Final GRC is established by adding all correction factors (i.e. -1-1-0=-2) and adapting the GRC by the resulting number (3-2=1).

(g) If the Final GRC is higher than 7, the operation is not supported by the SORA process.

2.4 The Air Risk Process

2.4.1 Air Risk Process Overview

(a) The SORA uses the operational airspace defined in the ConOps as the baseline to evaluate the intrinsic risk of mid-air collision and by determining the air risk category (ARC). The ARC may be modified/lowered by applying strategic and tactical mitigation means. Application of strategic mitigations may lower the ARC level. An example of strategic mitigations to reduce collision risk may be by operating during certain times or within certain boundaries. After applying strategic mitigations any residual risk of mid-air collision is addressed by means of tactical mitigations.

(b) Tactical mitigations take the form of detect and avoid systems or alternate means, such as ADS-B, FLARM, UTM/U-Space services or operational procedures. Depending on the residual risk of mid-air collision, the Tactical Mitigation Performance Requirement(s) may vary.

(c) As part of the SORA process, the Operator should cooperate with the relevant service provider for the airspace (e.g. ANSP or UTM/U-Space service provider) and obtain the necessary authorizations. Additionally, generic local authorisations or local procedures allowing access to a certain portion of controlled airspace may be used if available (e.g. Low Altitude Authorization and Notification Capability – LAANC – system in the United States).

(d) The SORA recommends, that irrespective of the results of the risk assessment, the operator pay particular attention to all features that may increase the detectability of the UA in the airspace. Therefore, technical solutions that improve the electronic conspicuousness or detectability of the UAS is recommended.

2.4.2 Step #4 - Determination of the Initial Air Risk Class (ARC)

(a) The competent authority, ANSP, or UTM/U-space service provider, may elect to directly map the airspace collision risks using airspace characterization studies. These maps would directly show the initial Air Risk Class (ARC) for a particular airspace. If the competent authority, ANSP, or UTM/U-space service provides an air collision risk map (static or dynamic), the applicant should use that service to determine the initial ARC, and go directly to section 2.4.3 “Application of Strategic Mitigations” to reduce the initial ARC.

2.4.2.1 Determination of Initial ARC

(a) As seen in Figure 4, the airspace is categorized into 13 aggregated collision risk categories. These categories were characterized by 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.

(b) To find the proper ARC for the type of UAS operation, the applicant should use the decision tree found in Figure 4.

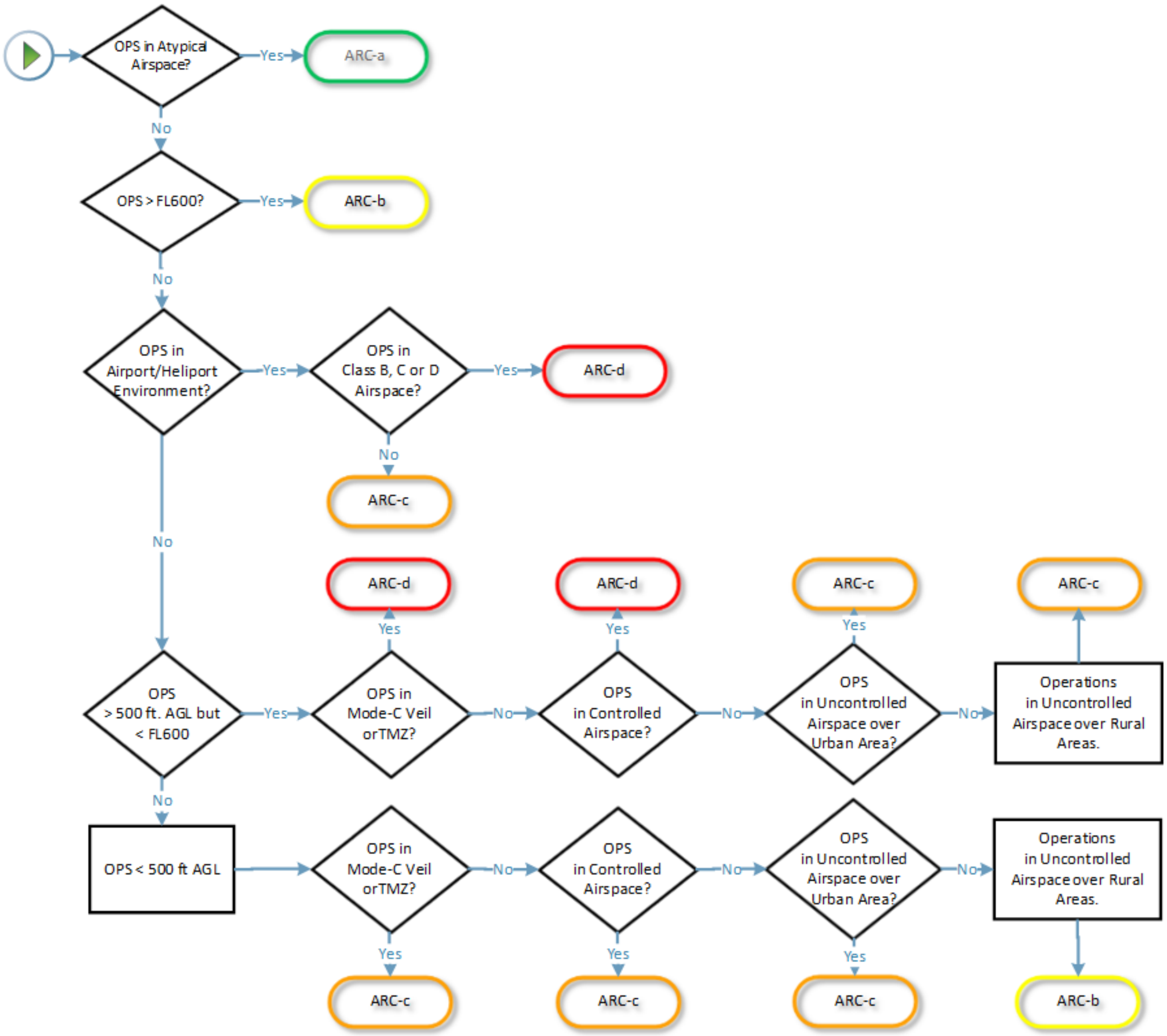

Figure 4 – ARC assignment process

(c) The ARC is a qualitative classification of the rate at which a UAS would encounter a manned aircraft in typical generalized civil airspace. The ARC is an initial assignment of the aggregated collision risk for the airspace, before mitigations are applied. Actual collision risk of a specific local Operational Volume could be much different and can be addressed in the Application of Strategic Mitigations to reduce the ARC section (this step is optional, see section 2.4.3, Step #5).

(d) Although the static generalized risk put forward by the ARC is conservative (i.e stayed on the safe side), there may be situations where that conservative assessment may not suffice. It is important that both the competent authority and operator take great care to understand the Operational Volume and under what circumstances the definitions in Figure 4 could be invalidated. In some situations, the competent authority may raise the Operational Volume ARC to a level which is higher than that advocated by the Figure 4. The ANSP should be consulted to assure that the assumptions related to the Operational Volume are accurate.

(e) ARC-a is generally defined as airspace where the risk of collision between a UAS and manned aircraft is acceptable without the addition of any tactical mitigation.

(f) ARC-b, ARC-c, ARC-d are generally defining airspace with increasing risk of collision between a UAS and manned aircraft.

(g) During the UAS operation, the UAS Operational Volume may span many different airspace environments. The applicant needs to do an air risk assessment for the entire range of the Operational Volume. An example scenario of operations in multiple airspace environments is provided at the end of Annex C.

2.4.3 Step #5 – Application of Strategic Mitigations to determine Residual ARC (optional)

(a) As stated before, the ARC is a generalized qualitative classification of the rate at which a UAS would encounter a manned aircraft in the specific airspace environment. However, it is recognized that the UAS Operational Volume may have collision risk different than the generalized Initial ARC assigned.

(b) If an applicant considers that the generalized Initial ARC assigned is too high for the condition in the local Operational Volume, then refer to Annex C for the ARC reduction process.

(c) If the applicant considers that the generalized Initial ARC assignment is correct for the condition in the local Operational Volume, then that ARC becomes the Residual ARC

2.4.4 Step #6 – Tactical Mitigation Performance Requirement (TMPR) and Robustness Levels

(a) Tactical Mitigations are applied to mitigate any residual risk of a mid-air collision needed to achieve the applicable airspace safety objective. Tactical Mitigations will take the form of either “See and Avoid” (i.e. operations under VLOS) or may require a system which provides an alternate means of achieving the applicable airspace safety objective (operation using a DAA, or multiple DAA systems). Annex D provides the method for applying Tactical Mitigations.

2.4.4.1 Operations under VLOS/EVLOS

(a) VLOS is considered an acceptable Tactical Mitigation for collision risk for all ARC levels. Notwithstanding the above, the operator is advised to consider additional means to increase situational awareness with regard to air traffic operating in the vicinity of the operational volume.

(b) Operational UAS flights under VLOS do not need to meet the TMPR, nor the TMPR robustness requirements. In the case of multiple segments of the flight, those segments done under VLOS do not have to meet the TMPR nor the TMPR robustness requirements, whereas those done BVLOS do need to meet the TMPR and the TMPR robustness requirements.

(c) In general, all VLOS requirements are applicable to EVLOS. EVLOS may have additional requirements over and above VLOS. EVLOS verification and communication latency between pilot and observers should be less than 15 seconds.

(d) Notwithstanding the above, the applicant should have a documented VLOS de-confliction scheme, in which the applicant explains which methods will be used for detection, and define the associated criteria applied for the decision to avoid incoming traffic. In case the remote pilot relies on detection by observers, the use of phraseology will have to be described as well.

(e) For VLOS operations, it is assumed that an observer is not able to detect traffic beyond 2 NM. (Note that the 2 NM range is not a fixed value and may largely depend on atmospheric conditions, aircraft size, geometry, closing rate, etc.) Therefore, the operator may have to adjust the operation and /or procedures accordingly.

2.4.4.2 Operations under a DAA System - Tactical Mitigation Performance Requirement (TMPR)

(a) For operations other than VLOS, the applicant will use the Residual ARC and Table 4 below to determine the Tactical Mitigation Performance Requirement (TMPR).

Residual ARC	Tactical Mitigation Performance Requirements (TMPR)	TMPR Level of Robustness
ARC-d	High	High
ARC-c	Medium	Medium
ARC-b	Low	Low
ARC-a	No requirement	No requirement

Table 4 – Tactical Mitigation Performance Requirement (TMPR) and TMPR Level of Robustness Assignment

(b) <u>High TMPR (ARC-d)</u>: This is airspace where either the manned aircraft encounter rate is high, and/or the available Strategic Mitigations are Low. Therefore, the resulting residual collision risk is high, and the TMPR is also high. In this airspace, the UAS may be operating in Integrated Airspace and will have to comply with the operating rules and procedures applicable to that airspace, without reducing existing capacity, decreasing safety, negatively impacting current operations with manned aircraft, or increasing the risk to airspace users or persons and property on the ground. This is no different than the requirements for the integration of comparable new and novel technologies in manned aviation. The performance level(s) of those Tactical mitigations and/or the required variety of Tactical mitigations is generally higher than for the other ARCs. If operations in this airspace are conducted more routinely, the competent authority is expected to require the operator to comply with the recognised DAA system standards (e.g. those developed by RTCA SC-228 and/or EUROCAE WG-105).

(c) <u>Medium TMPR (ARC-c)</u>: A medium TMPR will be required for operations in airspace where the chance to encounter manned aircraft is reasonable and/or the Strategic Mitigations available are medium. Operations with a medium TMPR will likely be supported by systems currently used in aviation to aid the pilot with detection of other manned aircraft, or on systems designed to support aviation that are built to a corresponding level of robustness. Traffic avoidance manoeuvres could be more advanced than for a low TMPR.

(d) <u>Low TMPR (ARC-b)</u>: A low TMPR will be required for operations in airspace where the probability of encountering another manned aircraft is low but not negligible and/or where Strategic Mitigations address most of the risk and the resulting residual collision risk is low. Operations with a low TMPR are supported by technology that is designed to aid the pilot in detecting other traffic, but which may be built to lesser standards. For example, for operations below 500ft, the traffic avoidance manoeuvres are expected to mostly be based on a rapid descent to an altitude where manned aircraft are not expected to ever operate.

(e) No Performance Requirement (ARC-a): This is airspace where the manned aircraft encounter rate is expected to be extremely low, and therefore there is no requirement for a TMPR[g]. It is generally defined as airspace where the risk of collision between a UAS and manned aircraft is acceptable without the addition of any Tactical mitigation. An example of this may be UAS flight operations in some parts of Alaska or northern Sweden where the manned aircraft density is so low that the airspace safety threshold could be met without any tactical mitigation.

(f) Annex D provides information on how to satisfy the TMPR based on the available tactical mitigations and the TMPR Level of Robustness.

2.4.4.3 Consideration of Additional Airspace / Operation Requirements

(a) Modifications to the initial and subsequent approvals may be required by the competent authority or ANSP as safety and operational issues arise.

(b) The operator and competent authority need to be cognizant that the ARCs are a generalized qualitative classification of collision risk. Local circumstances could invalidate the aircraft density assumptions of the SORA, for example with special events. It is important that both the competent authority and operator fully understand the airspace and air-traffic flows and develop a system which can alert operators to changes to the airspace on a local level. This will allow the operator to safely address the increased risks associated with these events.

(c) There are many airspace, operational and equipage requirements which have a direct impact on the collision risk of all aircraft in the airspace. Some of these requirements are general and apply to all airspaces, while some are local and are required only for a particular airspace. The SORA cannot possibly cover all the possible requirements required by the competent authority for all conditions in which the operator may wish to operate. The applicant and the competent authority need to work closely together to define and address these additional requirements.

(d) The SORA process should not be used to support operations of a UAS in a given airspace without the UAS being equipped with the required equipment for operations in that airspace (e.g. equipment required to ensure interoperability with other airspace users). In these cases, specific exemptions may be granted by the competent authority. Those exemptions are outside the scope of the SORA.

(e) Operations in controlled airspace, an airport/heliport environment or a Mode-C Veil/Transponder Mandatory Zone (TMZ) will likely require prior approval from the ANSP. The applicant should pay attention to involve the ANSP/authority prior to commencing operations in these environments.

2.5 Final Specific Assurance and Integrity Levels (SAIL) and Operational Safety Objectives (OSO) Assignment

2.5.1 Step #7 SAIL determination

(a) The SAIL parameter consolidates the ground and air risk analyses and drives the required activities. The SAIL represents the level of confidence that the UAS operation will stay under control.

(b) After determining the Final GRC and Residual ARC, it is now possible to derive the SAIL associated with the proposed ConOps.

(c) The level of confidence that the operation will remain in control is represented by the SAIL. The SAIL is not quantitative but instead corresponds to:

[g] Please refer to annex G, section 3.19 SORA Definition of Encounter.

- Operational Safety Objectives (OSO) to be complied with (see table 6),
- Description of activities that might support compliance with those objectives, and
- The evidence that indicates the objectives have been satisfied.

(d) The SAIL assigned to a particular ConOps is determined using Table 5

SAIL Determination				
	Residual ARC			
Final GRC	a	b	c	d
≤2	**I**	**II**	**IV**	**VI**
3	**II**	**II**	**IV**	**VI**
4	**III**	**III**	**IV**	**VI**
5	**IV**	**IV**	**IV**	**VI**
6	**V**	**V**	**V**	**VI**
7	**VI**	**VI**	**VI**	**VI**
>7	Category C operation			

Table 5 – SAIL determination

2.5.2 Step #8 - Identification of Operational Safety Objectives (OSO)

(a) The last step of the SORA process is to use the SAIL to evaluate the defenses within the operation in the form of operational safety objectives (OSO) and to determine the associated level of robustness. Table 6 provides a qualitative methodology to make this determination. In this table, O is Optional, L is recommended with Low robustness, M is recommended with Medium robustness, H is recommended with High robustness. The various OSOs are grouped based on the threat they help to mitigate; hence some OSOs may be repeated in the table.

(b) Table 6 is a consolidated list of common OSOs that historically have been used to ensure safe UAS operations. It represents the collected experience of many experts and is therefore a solid starting point to determine the required safety objectives for a specific operation. Competent authorities may define additional OSOs for a given SAIL and the associated level of robustness.

OSO Number (in line with Annex E)		**SAIL**					
		I	**II**	**III**	**IV**	**V**	**VI**
	Technical issue with the UAS						
OSO#01	Ensure the operator is competent and/or proven	O	L	M	H	H	H
OSO#02	UAS manufactured by competent and/or proven entity	O	O	L	M	H	H

OSO Number (in line with Annex E)		SAIL					
		I	II	III	IV	V	VI
OSO#03	UAS maintained by competent and/or proven entity	L	L	M	M	H	H
OSO#04	UAS developed to authority recognized design standards[h]	O	O	O	L	M	H
OSO#05	UAS is designed considering system safety and reliability	O	O	L	M	H	H
OSO#06	C3 link performance is appropriate for the operation	O	L	L	M	H	H
OSO#07	Inspection of the UAS (product inspection) to ensure consistency to the ConOps	L	L	M	M	H	H
OSO#08	Operational procedures are defined, validated and adhered to	L	M	H	H	H	H
OSO#09	Remote crew trained and current and able to control the abnormal situation	L	L	M	M	H	H
OSO#10	Safe recovery from technical issue	L	L	M	M	H	H
	Deterioration of external systems supporting UAS operation						
OSO#11	Procedures are in-place to handle the deterioration of external systems supporting UAS operation	L	M	H	H	H	H
OSO#12	The UAS is designed to manage the deterioration of external systems supporting UAS operation	L	L	M	M	H	H
OSO#13	External services supporting UAS operations are adequate to the operation	L	L	M	H	H	H
	Human Error						
OSO#14	Operational procedures are defined, validated and adhered to	L	M	H	H	H	H
OSO#15	Remote crew trained and current and able to control the abnormal situation	L	L	M	M	H	H
OSO#16	Multi crew coordination	L	L	M	M	H	H
OSO#17	Remote crew is fit to operate	L	L	M	M	H	H
OSO#18	Automatic protection of the flight envelope from Human Error	O	O	L	M	H	H
OSO#19	Safe recovery from Human Error	O	O	L	M	M	H
OSO#20	A Human Factors evaluation has been performed and the HMI found appropriate for the mission	O	L	L	M	M	H

[h] The robustness level does not apply to mitigations for which credit has been taken to derive the risk classes. This is further detailed in para. 3.2.11(a).

OSO Number (in line with Annex E)		SAIL					
		I	II	III	IV	V	VI
	Adverse operating conditions						
OSO#21	Operational procedures are defined, validated and adhered to	L	M	H	H	H	H
OSO#22	The remote crew is trained to identify critical environmental conditions and to avoid them	L	L	M	M	M	H
OSO#23	Environmental conditions for safe operations defined, measurable and adhered to	L	L	M	M	H	H
OSO#24	UAS designed and qualified for adverse environmental conditions	O	O	M	H	H	H

Table 6 – Recommended operational safety objectives (OSO)

2.5.3 Step #9 – Adjacent Area/Airspace Considerations

(a) The objective of this section is to address the risk posed by a loss of control of the operation resulting in an infringement of the adjacent areas on the ground and/or adjacent airspace. These areas may vary with different flight phases.

(b) Safety requirements for containment are:

> 1. No probable[i] failure[j] of the UAS or any external system supporting the operation shall lead to operation outside of the operational volume.
>
> *Compliance with the requirement above shall be substantiated by a design and installation appraisal and shall minimally include:*
>
> *- design and installation features (independence, separation and redundancy);*
>
> *- any relevant particular risk (e.g. hail, ice, snow, electro-magnetic interference…) associated with the ConOps.*

(c) The following three safety requirements apply for operations conducted:

- Where adjacent areas are:
    - i. Gatherings of people unless already approved for operations over gathering of people OR
    - ii. ARC-d unless the residual ARC is ARC-d
- In populated environments where
    - i. M1 mitigation has been applied to lower the GRC

[i] *The term “probable” needs to be understood in its qualitative interpretation, i.e. “Anticipated to occur one or more times during the entire system/operational life of an item.”*
[j] *The term “failure” needs to be understood as an occurrence, which affects the operation of a component, part, or element such that it can no longer function as intended. Errors may cause failures but are not considered as failures. Some structural or mechanical failures may be excluded from the criterion if it can be shown that these mechanical parts were designed to aviation industry best practices.*

ii. Operating in a controlled ground area

1. The probability of leaving the operational volume shall be less than 10^{-4}/FH. 2. No single failure[k] of the UAS or any external system supporting the operation shall lead to operation outside of the ground risk buffer. *Compliance with the requirements above shall be substantiated by analysis and/or test data with supporting evidence.* 3. Software (SW) and Airborne Electronic Hardware (AEH) whose development error(s) could directly lead to operations outside of the ground risk buffer shall be developed to an industry standard or methodology recognized as adequate by the competent authority.

As it is not possible to anticipate all local situations, the operator, the competent authority and the ANSP should use sound judgement with regards to the definition of “adjacent airspace” as well as “adjacent areas”. For example, for a small UAS with limited range, it is not intended to include busy airport/heliport environments 30 kilometres away. The airspace bordering the UAS volume of operation should be the starting point of the determination of adjacent airspace. In exceptional cases, the airspace(s) beyond those bordering the UAS volume of operation may also have to be considered.

2.6 Step #10 Comprehensive Safety Portfolio

(a) The SORA process provides the applicant, the competent authority and the ANSP with a methodology which includes a series of mitigations and safety objectives to be considered to ensure an adequate level of confidence that the operation can be safely conducted. These are:

- Mitigations used to modify the intrinsic GRC
- Strategic mitigations for the Initial ARC
- Tactical mitigations for the Residual ARC
- Adjacent Area/Airspace Considerations
- Operational Safety Objectives

(b) Satisfactory substantiation of the mitigations and objectives required by the SORA process provides a sufficient level of confidence that the proposed operation can be safely conducted.

(c) The operator should make sure to address any additional requirements not identified by the SORA process (e.g. security, environmental protection, etc.) and identify the relevant stakeholders (e.g. environmental protection agencies, national security bodies, etc.). The activities performed within the SORA process will likely address those additional needs but may not be considered sufficient at all times.

(d) The operator should ensure the consistency between the SORA safety case and the actual operational conditions (i.e. at time of flight).

[k] *Same as footnote “m” above.*