Safety Risk Management Methodologies (SRM)

Specific Operations Risk Assessment (SORA)

This document was developed by the Safety Management Panel (SMP). It is intended to support safety experts in the application of safety risk management methodologies. Any comments to this material should be forwarded to safetymanagement@icao.int.

Version 0.2 – October 2022

1. Description

1.a) Purpose of the methodology

The Specific Operation Risk Assessment (SORA) methodology was developed by the Joint Authorities for Rulemaking of Unmanned Systems (JARUS)[1] through the *JARUS guidelines on Specific Operations Risk Assessment (SORA) (2nd edition – 2019).* The *JARUS guidelines on Specific Operations Risk Assessment (SORA) are* complemented by a series of Annexes all published as separate documents[2]:

- Annex A - Guidelines on collecting and presenting system and operation information for a specific UAS operation
- Annex B - Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class
- Annex C - Strategic Mitigation Collision Risk Assessment
- Annex D - Tactical Mitigation Collision Risk Assessment
- Annex E - Integrity and assurance levels for the Operation Safety Objectives (OSO)
- Annex I - Glossary of Terms

SORA provides a safety risk assessment methodology to guide both the applicant and the competent authority (National Aviation Authority) in evaluating the safety risks and determining whether an Unmanned Aircraft System (UAS) operation in the 'specific' category can be created, evaluated and conducted in a safe manner. The types of harm resulting as a consequence of a realized risk considered by the SORA methodology are:

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

SORA advocates for the evaluation of the intended Concept of Operation (ConOps) of the UAS and suggests that this ConOps is then categorized into one of six different Specific Assurance and Integrity Levels (SAIL) with operational safety objectives to be met for each SAIL. SORA can be used as a means by which an operator is granted approval by certifying authorities to operate within the limitations set forth by the authorities for specific category UAS operations. Specific category operations are those UAS operations that present greater risk than open (very low risk) operations and less risk than certified category operations which typically require more formal regulatory vigor.

The SORA methodology was developed in response to the rapidly increasing UAS operations across all States which have a generally different risk profile to conventional aviation. Unlike crewed aircraft, UAS operations did not have an existing regulatory system governing manufacturing, training, airworthiness or

[1] JARUS is a group of experts from the National Aviation Authorities (NAAs) and regional aviation safety organizations (independent of ICAO) that recommends technical, safety, and operational requirements to safely integrate Unmanned Aircraft Systems (UAS) into aviation. JARUS provides guidance material to facilitate each authority to write their own requirements and avoid duplicated efforts.

[2] Annex's F, G, H and J are currently under development by JARUS.

operations. The traditional regulatory processes and requirements for conventional aviation were overburdensome and not fit for purpose when it came to considering UAS regulation. In addition, UAS technology was far outpacing regulatory requirements and where regulations did exist, they differed from State to State and lacked global consensus or harmonization. In response JARUS created SORA to provide a global, standardized harmonized risk assessment methodology for the initial approval of each specific UAS operation.

The SORA methodology is not intended to be used to consider the risks of any operations other than UAS or '*un-personned*'[3] operations more generally. While the theoretical basis of the methodology could be applied to other novel aviation operations / systems this would require significant changes to the current SORA methodology.

1.b) Theoretical basis (Model)

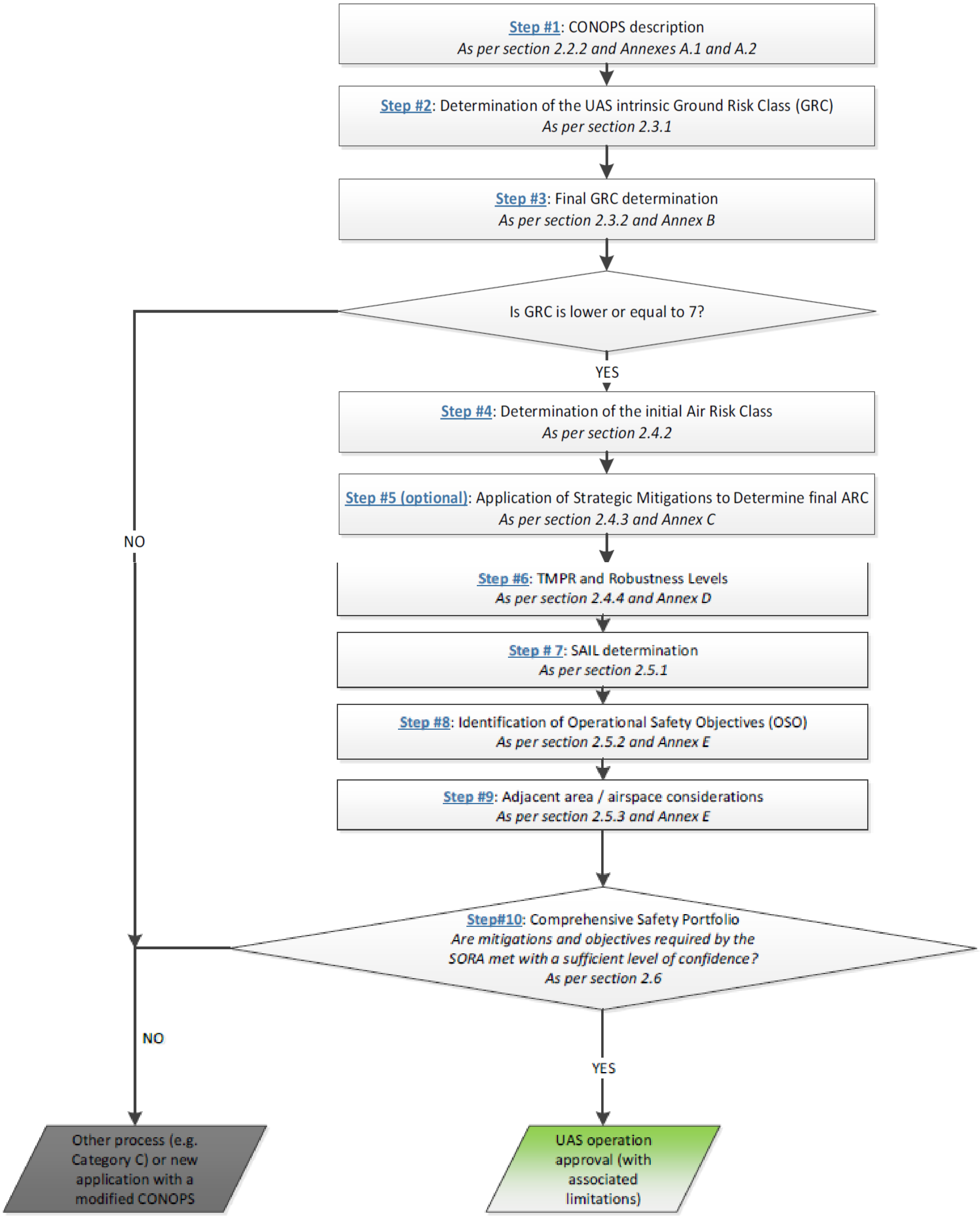
The SORA methodology is based on the principle of a holistic/total system safety risk-based assessment model used to evaluate the safety risks related when creating, evaluating and conducting an UAS operation. The SORA methodology considers all natures of threats associated with a specified hazard, the relevant design, and the proposed operational mitigations for a specific operation. The SORA then helps to evaluate the risks systematically and determines the boundaries required for a safe operation.

The SORA method allows UAS applicants to determine acceptable risk levels and to validate that those levels are complied with by their proposed operations. The methodology can also be used by the competent authority to gain confidence that the operator can conduct the operation safely.

The SORA methodology provides a standardized ten step process to analyze the ground and air risk of the proposed ConOps and to then establish an adequate level of confidence that the operation can be conducted with an acceptable level of safety risk.

[3] Uncrewed aircraft system carrying no people.

Figure 1 - The SORA process



Step #1: ConOps Description

Develop a comprehensive description of the types of operations being conducted by an UAS including where the operations will be taking place. This sets the context of the UAS, the type of operations being conducted, by who and where the operations will take place.

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

The intrinsic UAS ground risk relates to the risk of a person(s) being struck by the UAS (in the case of loss of UAS control with a reasonable assumption of safety.) The intrinsic GRC (score) is derived based on the UAS characteristics (dimensions/kinetic energy) and the intended operations (as defined in the ConOps Description) without the application of any further controls.

Step #3: Final GRC Determination

The final GRC is determined by considering the controls (mitigations) that can be used to reduce the risk and the robustness of each control. This step applies a 'correction factor' to the intrinsic GRC (score) determined in Step #2 based on the applied mitigants (controls) and their robustness.

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

Determines the intrinsic risk of mid-air collision by determining the initial air risk category (ARC) based on where (in which airspace) the operations will occur (as defined in the ConOps Description). A flow chart is used to classify the initial ARC into one of four aggregated collision risk categories (ARC-a, ARC-b, ARC-c or ARC-d) in which the risk of collision between a UAS and a manned aircraft is broadly categorized as meeting the target level of safety performance without further mitigation (ARC-a) or of increasing residual risk (ARC-b, ARC-c or ARC-d).

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

Strategic mitigations can then be applied, if needed (where the collision risk category is not acceptable) to the reduce the initial ARC to an acceptable level. Strategic Mitigation can include procedures and operational restrictions intended to reduce the UAS encounter rates or time of exposure and are implemented prior to the commencement of UAS activities (prior to take-off). Strategic Mitigations can be further classified as those controlled by the UAS operator (mitigations by operational restrictions) e.g. restriction operations to certain areas or at certain times and those that cannot be controlled by the UAS operator (mitigations by common structures) e.g. common flight rules or airspace structure. A residual ARC is determined following application of Strategic Mitigations

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

The residual ARC (following Step #5) is used to determine the appropriate TMPR – defined as either high, medium, low or no requirement as well as the TMPR level of robustness requirements.

A tactical mitigation is one that is applied after the commencement of a UAS activity (after take-off) and can be classified as Visual Line of Sight (VLOS) e.g. see and avoid or Beyond Visual Line of Sight (BVLOS) e.g. detect and avoid.

VLOS is considered an acceptable Tactical Mitigation for collision risk for all ARC levels. If conducting BVLOS operations, In general, the higher the risk associated with the residual ARC the greater the TMPR and TMPR robustness requirements that the operator will need to apply.

Step #7: Specific Assurance and Integrity Levels (SAIL) determination

The SAIL represents the level of confidence that the UAS operation will stay under control within the boundaries of the intended operation. The SAIL is determined by considering the final GRC (from Step #3) and the residual ARC (from Step #5). The SAIL is represented within the 'specific category' as a level (from I-VI).

Step #8: Identification of Operational Safety Objectives (OSO)

The SAIL (determined in Step #7) is then used to determine the necessary defenses for the operation in the form of operational safety objectives (OSO) and to determine the associated level of robustness for each OSO. The series of typical defences (OSOs) are pre-defined with the SORA methodology. Each OSO (defence) is assigned a mandatory level of robustness for the determined SAIL level; Optional (O), Low (L), Medium (M) or High (H), that the Competent Authority should consider when assessing an UAS application. Competent authorities may define additional OSOs that they consider necessary to manage identified risks and then for each OSO identified, defined the necessary level of robustness for a given SAIL.

Step #9: Adjacent Area/Airspace Considerations

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 is considered and safety requirements for containment and/or reduction are established.

Step #10: Comprehensive Safety Portfolio

The operator should make sure to address any additional requirements not identified by the SORA process and that their operations are consistent between the SORA safety case and the actual operational conditions.

In this step the applicant takes all of the analysis from the previous SORA steps and collates the required evidence to meet their claimed mitigations/OSOs/TMPRs/containment requirements. By completing this step, a robust safety argument aligned with the SORA process is created, and able to be presented to the competent authority for review.

1.c) Risk acceptance method and criteria (where applicable)

The ten step SORA methodology is designed to establish an adequate level of confidence that the proposed UAS operation can be conducted with an acceptable level of risk. The SORA model is based on the JARUS policy that, *'UAS operations shall not pose more risk than conventional aviation operations'.*

In simple terms the SORA is designed so that the more risk presented by the UAS operations the greater the level of safety controls required and the more assurance that is required to prove the controls are working as intended. This is the basis of the concept of robustness. Each control can be demonstrated at differing levels of robustness, that is the level of integrity (i.e. safety gain) provided by each control, and the level of assurance (i.e. the level of confidence in the integrity of the control) that the claimed safety gain has been achieved.

Risk acceptance is inherent within the SORA process where those operations with higher SAILs are required to implement / prove additional controls (OSOs) at a greater level of robustness (Step #8) – with a greater safety gain and/or level of assurance.

1.d) Key terms and definitions (e.g. hazard/threat, likelihood/probability, severity)

Key terms used in the SORA methodology are defined in the *JARUS guidelines on SORA Annex I Glossary of Terms.* An extract of key terms are included in Table 1.

Table 1 – JARUS guidelines on SORA key risk related terms and definitions

Term	**SORA Definition**
Acceptable (level of) risk	The level of risk that individuals or groups are willing to accept given the benefits gained. Each organization will have its own acceptable risk level, which is derived from its legal and regulatory compliance responsibilities, its threat profile, and its business/organizational drivers and impacts.
Accident	An unplanned event or series of events that results in death, injury, or damage to, or loss of, equipment or property.
Airspace Risk Class	The ARC is an initial assignment of generic collision risk of airspace, before mitigations are applied. ARC is assigned to AEC based on a qualitative assessment of collision risk of generic types of airspace.
Assurance	The planned and systematic actions necessary to provide adequate confidence that a product or process satisfies given requirements.
Cause	Something that brings about an event; a person or thing that is the occasion of an action or state; a reason for an action or condition.
Concept of Operations (ConOps)	A user-oriented document that describes systems characteristics for a proposed system from a user's perspective. A CONOPS also describes the user organization, mission, and objectives from an integrated systems point of view and is used to communicate overall quantitative and qualitative system characteristics to stakeholders.
Control (safety risk)	A means to reduce or eliminate the effects of hazards.
Effect	The real or credible harmful outcome that has occurred or can be expected if the hazard occurs in the defined system state.
Frequency	The number of times that something happens during a particular period
harm	The term harm, for the purpose of this document, relates to undesired events defined as: a. Fatal injuries to third parties on the ground b. Fatal injuries to third parties in the air (Catastrophic MAC with a manned aircraft) c. Damage to critical infrastructure.
Harm likelihood estimation	The estimation (qualitative or quantitative) of the likelihood of the retained harm.
Hazard	A potentially unsafe condition resulting from failures, malfunctions, external events, errors, or a combination thereof.
Incident	An occurrence other than an accident that affects or could affect the safety of operations.
Likelihood	Estimation of the degree of confidence one may have in the occurrence of an event.
Likelihood estimation	The estimation (qualitative or quantitative) of the likelihood of the retained undesired event's harm.
Probability	The measure of the likelihood that an event will occur.
Risk	The frequency (probability) of occurrence and the associated level of hazard
Robustness	Strong and effective in all or most situations and conditions *A designation of the level of risk mitigation or operational safety objective. Achieved using level of integrity provided by each mitigation and the level of assurance that the claimed safety gain has been achieved. Expressed as low, medium or high.*
Safety	Safety is the state in which the risk of harm to persons or property is reduced to, and maintained at or below, an acceptable level through a continuing process of hazard identification and risk management.
Safety Risk	The composite of predicted severity and likelihood of the potential effect of a hazard.
Severity	The consequence or impact of a hazard's effect or outcome in terms of degree of loss or harm.

Threat	In the context of the Holistic Risk Model, a threat is defined as an occurrence that in the absence of appropriate threat barriers can potentially result in the hazard.

1.e) Data/Information Inputs

Completing the SORA methodology is an extensive and comprehensive assessment of all aspects of the intended UAS operations and requires operators to collect and include the relevant technical, operational and system information.

Table 2 details the types of data required when conducting the SORA methodology. Full details on the data/information inputs required to be considered/documented as part of the SORA process including examples are included in *JARUS guidelines on SORA Annex A Guidelines on collecting and presenting system and operation information for a specific UAS operation*

Table 2 – Types of data/information required for SORA

Organisation Information	Operations	Training	Technical Information	UAS Control
• Safety • Design and Production • Training • Maintenance • Crew • UAS Configuration Management	• Type of Operations • Standard Operating Procedures • Normal Operation Strategy • Abnormal operation and emergency operation • Accidents, incidents and mishaps	• Initial training and qualification • Procedures for maintenance of currency • Flight Simulation Training Devices • Training Program	• Airframe – *e.g. dimensions, mass etc* • Materials • Loads • Performance characteristics • Propulsion system – *e.g. type, fuel etc.* performance • Flight control surfaces and actuators • Sensors • Payloads	• Navigation • Autopilot • Flight control system • Control station • Detect and Avoid system • Geo-fencing • Ground Support Equipment • Command and Control link – including degradation, link lost • Safety features

1.f) Tools available (where applicable)

Currently there is not a published SORA template that could be used when developing an application based on the SORA methodology. While the methodology is fairly simple, the absence of such template and the varied nature of UAS operations will result in regulators receiving applications in varying formats. JARUS is currently drafting version 2.5 of the SORA methodology that will include a template to supporting applications using the SORA process and this is expected to be available in 2023.

While no generic SORA template has been produced, to support a Civil Aviation Authority (CAA) to develop standard scenarios JARUS has published the *JARUS guidelines on SORA JARUS-STS-01 Standard Scenario for Aerial Work Operations.* Such standard scenarios allow operators that meet specific operational characteristics (as defined in the standard scenario) to apply to the CAAs using the standard scenario applicant response in lieu of a full SORA (the SORA methodology has already been considered against the standard scenario).

In addition to those published by JARUS, some CAAs have published their own Standard Scenarios including the Civil Aviation Safety Authority of Australia which has published standard scenarios for:

- BVLOS operations near a vertical object(s) with a controlled ground environment
- BVLOS operations near a vertical object(s) with a sparsely populated ground environment
- BVLOS operations in a remote area within 3 NM of a registered or certified non-controlled aerodrome
- BVLOS operations in remote Australian airspace (below 400 ft AGL)
- BVLOS operations in remote Australian airspace (400 ft AGL to 5000 ft AMSL)

These standard scenarios are designed to reduce the effort required from an operator in applying for a task meeting the specific operational criteria defined in the scenario.

2. User Factors

2.a) Applications (e.g. general or sector-specific)

The SORA is specifically developed to evaluate the safety risks involved only with the '*un-personned*' operations. While able to be applied to any UAS class and size and type of operation (including military, experimental, R&D and prototyping) SORA was not intended or envisaged to be applied to any operations other than UAS. SORA is particularly suited, but not limited to "specific[4]" operations for which a hazard and risk assessment is required.

2.b) Users (e.g. general workforce, management, safety analysts, trainers)

The SORA methodology is primarily designed to be utilized by an UAS operator and the relevant CAA.

The SORA methodology supports the UAS operator to evaluate their intended operations, to systematically consider the associated risks and determine the boundaries required for a safe operation. This method allows the operator to determine acceptable risk levels and to validate that those levels are complied with by the proposed operations. Pilots employed by the operator will then be required to operate in accordance with the process determined to be necessary through the SORA methodology – this will be defined in the operator's procedures.

The CAA can also apply the SORA methodology to support their assessment of operator's application and the associated risk as well as to gain confidence that the operator can conduct the intended operations safely. This can include adapting some or all of the SORA methodology into their regulatory framework. CAAs can also use the SORA methodology to define "standard scenarios" for identified types of ConOps with known hazards and acceptable risk mitigations. This can support establishing the minimum

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

requirements for UAS operators to meet for a given ConOps and standardizing expectations for operators.

2.c) Evaluation of Complexity

The SORA methodology is an extensive process used to evaluate risk and determine the acceptability of a UAS operation in the 'specific' category. It is only intended to be applied to a defined type of UAS operations (specific category). As such the methodology is considered reasonably complex. Applying the methodology as an operator or regulator does require a comprehensive understanding of each of the steps as well as of the intended UAS operations. Personnel unfamiliar with the SORA process may find an initial application challenging without having first received specific SORA training or have comprehensively reviewed the available JARUS guidelines and supporting Annexes. Where training is unavailable, and personnel are unsure on any aspect of preparing a SORA assessment they should engage their CAA for further advice.

2.d) Availability of training

Training around the SORA methodology is increasingly offered across many States – mainly through UAS training organisations.

There is no formal SORA training standards or qualifications, and each training organisation appears to have developed their own training requirements based on the SORA methodology.

3. Quality and Consistency

3.a) Consistency/Differences from SMM Concepts, Terms and Definitions (e.g. flow from, hazard/source of risk, to: immediate outcome and ultimate consequence)

The meaning of the key risk related terms used within SORA are consistent in intent (although not identical) with the meanings in the *Safety Management Manual ICAO Doc 9859*.

Typical risks assessments conducted consistently with *Safety Management Manual* guidance are designed to consider the risk associated with one particular part (or change to a part) of the aviation system. For example, a risk assessment may consider a new type of activity but using an aircraft that has existing regulatory requirements for manufacture and airworthiness.

The SORA methodology is a novel risk assessment process designed to consider the risk associated with all aspects of an UAS operations including manufacturing, training, airworthiness, operations etc. It is a holistic risk assessment covering all aspects of the operations, that was largely unregulated or inconsistently regulated from State to State.

For this reason, as a risk assessment process SORA is not considered comparable to a consequence / likelihood assessment included in the *Safety Management Manual* in that SORA is not a universal methodology that can be applied to any risk type. While both SORA and the consequence/likelihood assessment in the SMM are designed to consider risk, the SORA process is a very specific methodology developed for a very specific purpose whereas the risk assessment methodologies suggested in the SMM are designed to be more universal and allow any type of risk to be considered and assessed.

The overall SORA process is broadly consistent with the bow tie risk assessment methodology. The identified operational safety objectives would be considered controls in a bow tie and they are grouped around the potential threats that the UAS operation faces. The level of robustness then required for each operational safety objective is similar to considering the control effectiveness of each control within a bow tie assessment.

3.b) Validity and reliability of outputs

The SORA methodology is designed to provide an easy-to-use qualitative risk assessment that is underpinned by extensive quantitative modelling and which ensure all necessary risk factors are considered. When prepared (operator) and/or assessed (CAA) by an appropriately competent person, the SORA assessment produces a comprehensive risk assessment of the operators UAS operations including consideration of strategic and tactical mitigations as well as operational safety objectives (controls).

Operators need to ensure that the SORA methodology is not just viewed as a ‘checklist’ but instead that for each step, the most appropriate mitigations are considered and implemented to reduce risk to an acceptable level. The output of the SORA methodology does not detail prescriptive requirements but instead states objectives that need to be met at various levels of robustness.

3.c) Overall pros and cons (i.e. strengths and limitations)

Pros	Cons
• Highly detailed process considering all aspects of UAS operations • Widely adopted practice globally. • Broad international consensus on suitability of methodology. • Increasingly available training options available across most regions. • Comprehensive but relatively straight forward process (once familiar with process). • Underpinned by quantitative modelling.	• Highly specialized risk assessment methodology only able to be applied to UAS operations. • Heavily reliant on qualitative data/inputs – limited quantitative input. • Requires an overall understanding of the process and intent – can take time to get a full understanding.

3.d) Team assessment of usability

The usability of the SORA methodology is assessed as being dependent on the level of familiarity (competence) that the operator or assessor has with SORA and the UAS activities to be conducted. Assuming both parties have adequate familiarity, the SORA methodology is considered to be useful and usable for the purpose for which it was designed.

4. Additional Information

4.a) Abbreviations

Abbreviations	Meaning
ARC	Air Risk Class
BVLOS	Beyond Visual Line of Sight
ConOps	Concept of Operations
JARUS	Joint Authorities for Rulemaking of Unmanned Systems
GRC	Ground Risk Class
NAA	National Aviation Authority
OSO	Operational Safety Objectives
SAIL	Specific Assurance and Integrity Levels
SMM	Safety Management Manual (ICAO Doc 9859)
SORA	Specific Operations Risk Assessment
TMPR	Tactical Mitigation Performance Requirement
UAS	Unmanned Aircraft System
VLOS	Visual Line of Sight

4.b) Literature - reference

- Joint Authorities for Rulemaking of Unmanned Systems, JARUS guidelines on Specific Operations Risk Assessment (SORA), Edition 2.0, 2019
- Joint Authorities for Rulemaking of Unmanned Systems, JARUS guidelines on SORA Annex A Guidelines on collecting and presenting system and operation information for a specific UAS operation, Edition 1.0, 2017
- Joint Authorities for Rulemaking of Unmanned Systems, JARUS guidelines on SORA Annex B Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class, Edition 1.0, 2019
- Joint Authorities for Rulemaking of Unmanned Systems, JARUS guidelines on SORA Annex C Strategic Mitigation Collision Risk Assessment, Edition 1.0, 2019
- Joint Authorities for Rulemaking of Unmanned Systems, JARUS guidelines on SORA Annex D Tactical Mitigation Collision Risk Assessment, Edition 1.0, 2019
- Joint Authorities for Rulemaking of Unmanned Systems, JARUS guidelines on SORA Annex E Integrity and assurance levels for the Operation Safety Objectives (OSO), Edition 1.0, 2019
- Joint Authorities for Rulemaking of Unmanned Systems, JARUS guidelines on SORA Annex I Glossary of Terms, Edition 1.0, 2017