Joint Authorities for Rulemaking of Unmanned Systems

JARUS guidelines on SORA

Annex C

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Strategic Mitigation Collision Risk Assessment

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Annex C: Strategic Mitigation - Collision Risk Assessment

1 Introduction – Air Risk Strategic Mitigations

The target audience for Annex C, is the UAS operator who wishes to demonstrate to the Competent Authority that the risk of a Mid Air Collision (MAC) in the operational volume is acceptably safe and to obtain, with concurrence from the ANSP, approval to operate in the particular airspace.

More particularly, this Annex C covers the process of how the operator justifies lowering of the initial assessment of Air Risk Class (ARC).

The Air Risk Model provides a holistic means to assess the risk of an encounter with manned aircraft. This provides guidance to both the operator and the Competent Authority in determining whether an operation can be conducted in a safe manner. The model does not provide answers to all the air risk challenges and should not be used as a checklist. This guidance provides the operator suitable mitigation means and thereby reduce the air risk to an acceptable level. This guidance does not contain prescriptive requirements but rather a set of objectives at various levels of robustness.

2 Principles

The SORA is used to establish an Initial ARC for an Operational Volume, only when the competent authority and ANSP has not already established one. The initial ARC is a generalized qualitative classification of the rate at which a UAS would encounter a manned aircraft in the Operation Volume. A Residual ARC is the classification after mitigations are applied. The UAS Operational Volume may have collision risk levels that differ from the generalized Initial ARC level. If this is assumed to be the case, this Annex provides a process to help the operator, competent authority, and ANSP work to lower the initial ARC through the application of strategic mitigations.

3 Air Risk Scope and Assumptions

The scope of this air risk assessment is designed to help the operator, Competent Authority and ANSP in determining the risk of collision with manned aircraft which are operated under the JARUS “specific” category. The scope of the air risk assessment does not include:

- The probability of UAS on UAS encounters
- Risks due to wake turbulences, adverse weather, CFIT, return to course function, lost link, or automatic response.

3.1 SORA Qualitative vs Quantitative Approach

This air risk assessment is qualitative in nature. Where possible, this assessment will use quantitative data to back up and support the qualitative assumptions. The SORA approach in general provides a balance between qualitative and quantitative approaches, as well as between known prescriptive and non-traditional methodologies.

3.2 SORA UTM/U-Space Assumptions

The SORA has used UTM/U-Space mitigations to a limited extent, because UTM/U-Space is in early stages of development. When UTM/U-Space provide adequate mitigations to limit the risk of UAS encounters with manned aircraft, an operator can apply for, and obtain credit for these mitigations whether they be Tactical or Strategic.

Annex H analyzes UTM/U-Space implications on the SORA.

3.3 SORA Flight Rules Assumptions

Today UAS flight operations under the specific category cannot fully comply with IFR and VFR rules as written. Although IFR infrastructures and mitigations are designed for manned aircraft operations (e.g. minimal safe altitudes, equipage requirements, operational restrictions, etc.), it may be possible for a UAS to comply with IFR requirements. UAS operating at very low levels (e.g. 500 ft. AGL and below) may technically comply with 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 Beyond Visual Line of Sight (BVLOS) a UAS cannot comply with VFR[1].

Given the above, for purposes of this risk assessment it is assumed that Competent Authority will address these shortcomings. All aircraft must adhere to specific flight rules to mitigate collision risk. Implementation of procedures and guidelines appropriate to the airspace structure, reduce collision risk for all aircraft. For instance there are equipage requirements based 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.

To be clear: The SORA does not provide a regulatory framework for states to apply with respect to airspace management, training, licensing, rules of the air, etcetera. This remains the responsibility of the aviation authorities in the sovereign states. The SORA Air Risk Model is a tool to assess the risks associated with unmanned aircraft operations in a particular airspace, and a method to determine whether those risks are within acceptable safety limits.

3.4 Regulatory Requirements, Safety Requirements, and Waivers

Regulations require all aircraft, manned and UAS, to “remain well clear from and avoid collisions with” other manned aircraft (c.f. ICAO Annex 2 section 3.2 and codified in 14 CFR 91.111, 113, 181, SERA 3201 and similar rules). The UAS is unable to “see and avoid” it must therefore employ an alternate means of compliance to meet the intent of “see and avoid”, which will have to be defined in terms of safety and performance for the UAS operation. When the risk of an encounter with manned aircraft is extremely low (i.e. in Atypical/Segregated Airspace) an alternate means of compliance may not be required. For example, in areas where the manned airspace density is so low, (e.g. in the case of low level operations in remote parts of Alaska or northern Sweden) the airspace safety threshold could be met with no additional mitigation. Operators need to understand that although the airspace may be technically safe

[1] A UAS operating under VLOS may be able to comply with VFR.

to fly from an air collision risk standpoint, it does not fulfill the 14 CFR 91.113, SERA 3201, or ICAO Annex 2 section 3.2 “See and Avoid” requirements.

To operate a UAS in manned airspace, two requirements must be met:

1. A safety requirement ensuring that the operation is safe to conduct in the operational volume
2. A requirement for regulatory compliance with ICAO Annex 2 section 3.2, 14 CFR 91.113, SERA 3201, etc. to “See and Avoid”.

These requirements must be addressed to the Competent Authority and/or ANSP through either:

- Demonstration of compliance to both requirements
- Demonstration of an alternate means of compliance to the requirements
- Waiver of the requirement(s) by the Competent Authority and/or ANSP.

The SORA provides a means to assess whether the air risks associated with UAS operations is within acceptable limits. To reiterate, the SORA does not provide a regulatory framework for states with respect to airspace management, training, licensing, rules of the air, etc., this remains the responsibility of the aviation authorities in the sovereign states.

3.5 SORA Assumptions on Threat Aircraft

This air risk assessment does not consider (for good or bad) the threat aircraft’s ability to remain well clear or to avoid collisions with the UAS in any part of the safety assessment.

3.6 SORA Assumptions on People Carrying UAS

This air risk model does not consider the notion of UAS carrying people, or urban mobility operations. The model and the assessment criteria are limited to the risk of encounter with manned aircraft, i.e. an aircraft piloted by a human on board.

3.7 SORA Assumptions on UAS Lethality

This air risk assessment assumes that a MAC between a UAS and manned aircraft is Catastrophic. Frangibility is not considered.

3.8 SORA Assertion that Separation Provision and Collision Avoidance are a “Tactical Process”

Contrary to ICAO Doc 9854, the SORA safety assessment makes no distinction between Separation Provision and Collision Avoidance; both are considered as one dependent system like “See and Avoid”. The SORA uses a continuum function that changes over time, beginning with a separation provision objective and progresses to collision avoidance objective. It assumes the pilot, supported by the systems that provide tactical mitigations, negotiates the encounter.

If a Competent Authority and/or ANSP wishes to make the distinction between Separation Provision and Collision Avoidance, or wishes justification as to why the SORA makes no distinction, please see Annex G.

4 General Air-SORA Mitigation Overview

To fully understand this section, a working knowledge of the following SORA definitions is needed:

- Atypical/Segregated vs. Typical Airspace (see Annex G or I)
- Aircraft Encounter Category (AEC - see Annex G or I)
- Air Risk Class (ARC - see Annex G or I)
- ICAO conflict management (see ICAO Doc. 9854, section 2.7)
- Feedback Loop (see Annex G or I)

The SORA recognizes and uses the three conflict management pillars defined in ICAO Doc. 9854;

- Strategic Mitigation
- Separation Provision
- Collision Avoidance

4.1 SORA Classification of Mitigations

The SORA classifies mitigations to suit the operational needs of a UAS in the “Specific” class. These mitigations are classified as:

- Strategic Mitigations by application of Operational Restrictions
- Strategic Mitigations by application of Common Structures and Rules
- Tactical Mitigations which include both the “tactical process” of a separation provision and collision avoidance

Figure 1 shows the alignment of mitigation definitions between ICAO and the SORA.

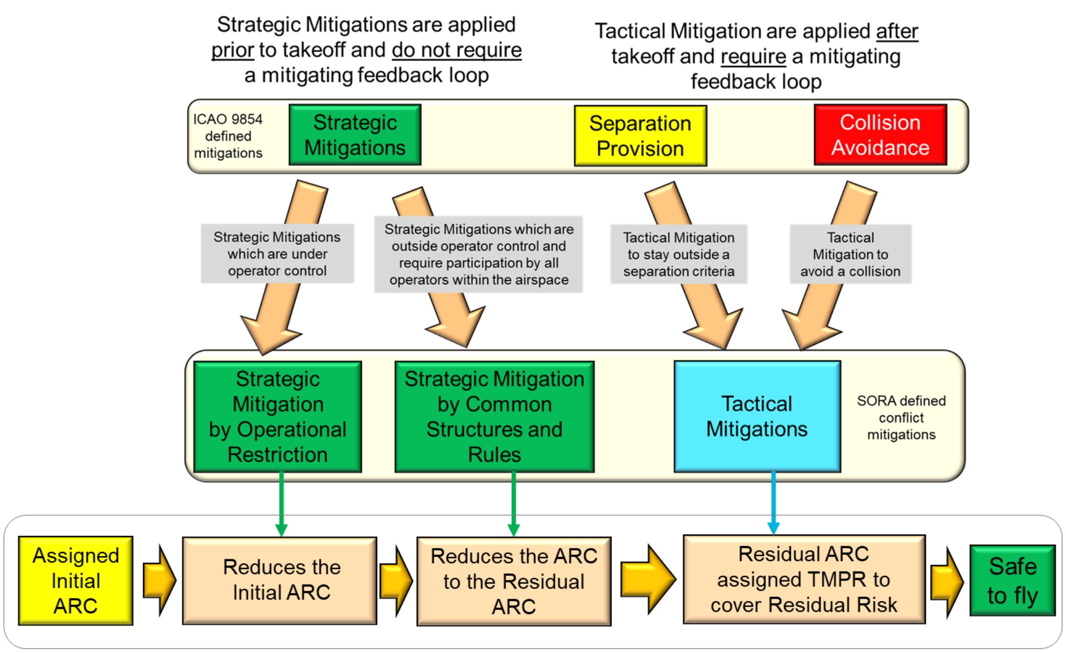

Figure 1; SORA Air-Conflict Mitigation Process

Further guidance on the classification of mitigations and the relationship of the SORA with the ICAO defined mitigations are provided in Annex G.

5 Air-SORA Strategic Mitigation

Strategic Mitigation consists of procedures and operational restrictions intended to reduce the UAS encounter rates or time of exposure, prior to take-off.

Strategic Mitigations are further divided into:

- Mitigations by Operational Restrictions which are mitigations that are controlled[2] by the UAS operator
- Mitigations by Common Structures[3] and Rules which are mitigations which cannot be controlled by the UAS operator

5.1 Strategic Mitigation by Operational Restrictions

Operational Restrictions are controlled[4] by the operator and intended to mitigate collision risk prior to take-off. This section provides details on Operational Restrictions, and examples on how these can be applied to UAS operations.

Operational Restrictions are the primary means an operator can apply to reduce collision risk using strategic mitigation(s). The most common Mitigations by Operational Restriction are:

- Mitigation(s) that bound the geographical volume in which the UAS operates (e.g. certain boundaries or airspace volumes)
- Mitigation(s) that bound the operational time frame (e.g. restricted to certain times of day, such as fly 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". Mitigation by exposure simply limits the time of exposure to the operational risk.

Mitigation that limit flight time or the exposure time to risk may be more difficult to apply. With this said, there is some precedence for this mitigation which has (in some cases) been accepted by the competent authority. Therefore, even though considered difficult, this mitigation strategy may be considered.

One example is the MEL (minimum equipment list) system that allows in certain situations a commercial airline to fly for three to ten days with an inoperative TCAS. The safety argument is that three days is a very short exposure time compared to the total life-time risk exposure of the aircraft. This short time of elevated risk exposure is justified to allow for the aircraft to return to a location where proper equipage maintenance can take place. Appreciating this may be a difficult argument for the UAS operation to make, the operator is still free to pursue this line of reasoning for a reduction in collision risk by applying a time of exposure argument.

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[2] The usage of the word "controlled" means that the operator is not reliant on the cooperation of other airspace users to implement an effective operational restriction mitigation strategy.

[3] This usage of the word "structure" means air structure, airways, traffic procedures and the like.

[4] The usage of the word "controlled" means that the operator is not reliant on the cooperation of other airspace users to implement an effect operational restriction mitigation strategy.

5.1.1 Example of Operation Restriction by Boundary

The operator intends to fly in a Class B airport airspace. The Class B airspace, as a whole, has a very high encounter rate. However, the operator wishes to operate at a very low altitude and at the very outer reaches of the Class B airspace where manned aircraft do not routinely fly. The operator draws up a new operational volume at the outer edge of the class B airspace and demonstrates how operations within the new Class B volume have very low encounter rates.

The operator may approach this scenario by requesting the competent authority to more precisely define the Airport Environment from the SORA perspective. The operator then considers the newly defined Airport Environment and provides an operational restriction that allows the UAS operation to safely remain inside the class B airspace, but outside newly defined SORA Airport Environment.

5.1.2 Example of Operation Restriction by Chronology

The operator wishes to fly in a Class B airport airspace. The Class B airspace, as a whole, has a very high encounter rate. However, the operator wishes to operate at a time of day when manned aircraft do not routinely fly. The operator then restricts the time schedule of the UAS operation and demonstrates that the new time (e.g. 03:00 / 3 AM and still within Class B) has very low encounter rates and is safe for operation.

5.1.3 Example of Operation Restriction by Time of Exposure

The operator wishes to cut the corner of a Class B airspace for flight efficiency. The operator demonstrates that even though the Class B airspace has a high encounter rate, the UAS is only exposed to that higher rate for a very short amount of time as it transitions the corner.

5.2 Strategic Mitigation by Common Structures[5] and Rules

Strategic Mitigation by Common Structures and Rules requires all aircraft within a certain class of airspace follow the same structures and rules; these structures and rules work to lower collision risk within the airspace. All aircraft in that airspace must participate and only the competent authorities and/or ANSP have the authority to set requirements for those aircraft. The UAS operator does not have control[6] over the existence or level of participation of the airspace structure or the application of the flight rules. Therefore, Strategic Mitigation by Common Structures and Rules is applied by the competent authorities and/or ANSP only. It is either available to the UAS operator, or not.

For example, imagine the situation if individual drivers could create their own driving rules to cover, direction, lanes, boundaries and speed. If the driving rules are different from one driver to another, no safety benefit is gained even though all are following rules (their own) and total chaos would ensue. However, if all drivers are compelled to follow the same set of rules, then traffic flow would be orderly with increased safety for all drivers. This is why a UAS operator cannot propose a mitigation schema requiring participation from other airspaces users that differs from that required by the competent authority.

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[5] This usage of the word “structure” means air structure, airways, traffic procedures and the like.

[6] The usage of the words “does not control” means that the operator does not have control over the implementation of aviation structures and rules and is reliant on the Competent Authority to implement structures and rules.

Most Strategic Mitigations by Common Structures and Rules will take the form of:

- Common Flight Rules
- Common Airspace Structure

Strategic Mitigations by common flight rules is accomplished by setting a common set of rules which all airspace users must comply with. These rules reduce air conflicts and/or make conflict resolution easier. Examples of common flight rules that reduce collision risk include right of way rules, implicit and explicit coordination schemes, conspicuity requirements, cooperative identification system, etc.

Strategic Mitigations by common airspace structure is accomplished by controlling the airspace infrastructure through, physical characteristics, procedures, and techniques that reduce conflicts or make conflict resolution easier. Examples of common flight airspace structures which reduce collision risk are airways, departure and approach procedures, airflow management, etc.

In the future as UTM/U-Space structures and rules become more readily defined and adopted, they will provide a source for UAS operations Strategic Mitigation by Common Structures and Rules that UAS operators could more easily apply.

5.2.1 Examples of Mitigation by Common Flight Rules.

The operator intends to fly in a volume of airspace in which the competent authority requires all UAS be equipped with an electronic cooperative system[7] and anti-collision lighting. The rules further require that the operator file a flight plan with the designated authority/ANSP/UTM/U-Space, etc.) and check for potential hazards along the whole flight route. These rules enhance the safety of the flight like a NOTAM. The operator should also have a system in place to check for high airspace usage in the intended operational volume (e.g. a completion of gliders or a fly-in). In those situations where the UAS operator does not own the airspace where the operational volume exists, the rules require the UAS operator to request permission prior to entering that airspace.

5.2.2 Examples of Mitigation by Common Airspace Structure

Example 1: The controlling authority established a transit corridor through Class B airspace that keeps the UAS separated from other non-UAS airport traffic and safely separates corridor traffic in one direction from traffic in the other direction. The UAS operator is intending to fly through this Class B airport airspace and hence must stay within the established transit corridor and adhere to transit corridor rules.

Example 2: The operator intends to fly a UAS from one location to another and files a flight plan with a UTM/U-space provider or the procedural separation system. As the UAS takes off, the UTM/U-space system then guarantees separation by procedural control of all aircraft in the airspace. Procedural controls are take-off windows, reporting points, assigned airways and altitudes, route clearances, etc. required for safe operation.

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[7] The installation of an Electronic cooperative system would make the UAS a Cooperative Aircraft in accordance with FAA Interim Operational Approval Guidance 08-01, "Unmanned Aircraft Systems Operations in the U.S. National Airspace System," Federal Aviation Administration, FAA/AIR-160, 2008.

6 Reducing Initial Air Risk Class (ARC) Assignment (optional)

This section is intended for an applicant that intends to use Strategic Mitigations to reduce the collision risk (i.e. ARC). There are two types of ARC:

- Initial ARC which is a qualitative classification of a UAS operational collision risk within an Operational Volume before Strategic Mitigations are applied.
- Residual ARC which is a qualitative classification of a UAS operational collision risk in an Operational Volume after all Strategic Mitigations are applied.

If an operator agrees that the (generalized) Initial ARC applicable to their operation and Operational Volume is correct, then this step is not necessary and the assessment should continue at SORA Step #6 (Assign DAA Tactical Performance Requirement and Robustness Levels based on Residual Collision Risk).

If mitigations to reduce the ARC are relevant and proposed, this section provides information and examples of how to use Strategic Mitigation(s) to lower the collision risk within the Operational Volume, and demonstrate the strategy to a competent authority and/or ANSP. The examples within the SORA, may or may not be applicable or acceptable to the competent authority, however the SORA encourages an open dialog between the applicant and the competent authority and/or ANSP to determine what is acceptable evidence.

6.1 Lowering Initial ARC to Residual ARC-a in any Operational Volume (optional)

ARC-a is intended for operations in Atypical/Segregated Airspace (see table 1). Lowering the Initial ARC to a Residual ARC-a requires a higher level of safety verification because allows an operator to operate without any tactical mitigation.

To demonstrate that an operation could be reduced to a Residual ARC-a, the operator must:

- Demonstrate that the Operational Volume can meet the requirements of SORA Atypical/Segregated Airspace (see Annex G, Section 3.20).
- Demonstrate compliance with any other requirements required by the competent authority and/or ANSP for the intended Operational Volume.

A Residual ARC-a assessment does necessarily exempt the UAS operator from the requirements to "see & avoid" and to "remain well clear" of other aircraft. Should the designated competent authority allow the operator a Residual ARC-a assessment for the operational volume, the operator must either provide a valid means and equipage as an alternate means of compliance for the "see and avoid" requirement, or the competent authority must waive the requirement to "see & avoid" and "remain well clear."

6.2 Lowering Initial ARC using Operational Restrictions (optional)

There may be many methods in which an operator may wish to demonstrate a suitable air risk and strategic mitigations. The SORA does not dictate how this is achieved and instead allows the applicant to propose and demonstrate the suitability and effectiveness of their Strategic Mitigations. It is important for both the operator, competent authority, and/or ANSP, to understand that the assessment may be qualitative in nature and where possible augmented with quantitative data to support the qualitative assumptions and decisions. The operator, competent authority, and/or ANSP, should understand there may not be a clear delineation in decision points, so common sense and safety of manned aircraft should be of paramount consideration.

The SORA provides a two-step method to reduce the air risk by operational mitigation. The first step is to determine the initial Air Risk Category using the potential Air Risk Encounter rate based on known airspace densities (Table 1). The second step is to reduce the initial risk through operator provided evidence that demonstrates the intended operation is more indicative of another airspace volume and encounter rate that corresponds to a lower risk classification (ARC); hence reducing the initial ARC to a residual ARC (Table 2). This requires agreement of the competent authority before the ARC may be reduced.

The SORA used expertise from subject matter experts to rate the 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. A small increase in one encounter rate variable can have major effects on collision risk, conversely a small increase in another variable could have limited effect on collision risks. 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. In summary:

- There are three inter-dependent variables effecting the ARC
- The contribution of each variable to the total collision risk is not the same
- For simplicity, the SORA only allows manipulation of one of the variables; proximity i.e. density.

The first step to potentially lowering the ARC is to determine the Airspace Encounter Category (AEC) and the associated density rating using Table 1. Twelve operational/airspace environments were considered for the SORA Air Risk classification and correspond to the twelve scenarios found in Figure 4 of the SORA Main Body.

Operational Environment, AEC and ARC.			
Operations in;	Initial Generalised Density Rating	Corresponding AEC	Initial ARC
Airport/Heliport Environment			
OPS in Airport/Heliport Environment in Class B, C or D airspace	5	AEC 1	ARC-d
OPS in Airport/Heliport Environment in Class E airspace or in Class F or G	3	AEC 6	ARC-c
Operations above 500 feet AGL but below Flight level 600			
OPS >500ft AGL but <FL600 in a Mode-S Veil or Transponder Mandatory Zone (TMZ)	5	AEC 2	ARC-d
OPS >500ft AGL but <FL600 in controlled airspace	5	AEC 3	ARC-d
OPS >500ft AGL but <FL600 in uncontrolled airspace over Urban Area	3	AEC 4	ARC-c
OPS >500ft AGL but <FL600 in uncontrolled airspace over Rural Area	2	AEC 5	ARC-c
Operations below 500 ft AGL			
OPS <500ft AGL in a Mode-S Veil or Transponder Mandatory Zone (TMZ)	3	AEC 7	ARC-c
OPS <500ft AGL in controlled airspace	3	AEC 8	ARC-c
OPS <500ft AGL in uncontrolled airspace over Urban Area	2	AEC 9	ARC-c
OPS <500ft AGL in uncontrolled airspace over Rural Area	1	AEC 10	ARC-b
Operations above Flight Level 600			
OPS >FL600	1	AEC 11	ARC-b
Operations in Atypical or Segregated Airspace			
OPS in Atypical/Segregated Airspace	1	AEC 12	ARC-a

Table 1

After determining the initial risk using Table 1, an applicant may choose to reduce that risk using Table 2. To understand table 2, the first Column shows the AEC in the environment in which the operator wishes to operate. Column A shows the associated airspace density rating for that AEC rated from 5 to 1, with 5 being very high density and, 1 being very low density.

Column B shows the corresponding initial ARC.

Column C is key to lowering the initial ARC. This column shows relative density ratings an operator should demonstrate to the competent authority in order 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) in Table 1. If this can be shown and accepted by the competent authority, the new lower ARC level as shown in Column D may be applicable.

As stated earlier, the operator is responsible to collect and analyze the airspace density and demonstrate the effectiveness of their proposal for Strategic Mitigations by Operational Restrictions to the competent authority. In summary the operator must demonstrate that restrictions imposed on the UAS operation can lower the risk of collision, by showing that the local airspace encounter rate, under the operational restrictions, is lower than the generalized AEC assessed encounter rate provided in Table 1.

The authors of the SORA believe that a 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 operator is trying to do, and where/when they want to do it. The Strategic Mitigation case as a safety case has two advantages. First it provides the operator with a structured approach to describe and capture the operation, hazards identified, risk analyzed, 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 understand the operator's intended operation and reasoning as to why a reduction in the ARC can be safely justified.

As each authority is different, the SORA recommends the applicant contact the competent authority and/or ANSP to determine the format and presentation of the Strategic Mitigation reduction case.

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 <500ft AGL over rural areas).				
AEC10 and AEC 11 are not included in this table as any ARC reduction would result in ARC-a. An operator claiming reduction to ARC-a must demonstrate that all requirements defining Atypical or Segregated Airspace of Annex G, section 3.20(d) have been met.				

Table 2

To more fully understand the above, the SORA provides three examples.

Example 1:

An operator is intending to operate in an airport/heliport environment, in Class C airspace, with a corresponding with AEC 1.

The operator enters the Initial ARC Reduction table at Row AEC 1. Column A, shows the generalized airspace density of this environment is 5. Column B shows the associated initial ARC as ARC-d. Column C indicates that if an operator can demonstrate that the actual, local airspace density corresponds to a generalized density rating of 3 or 4, then the ARC level may be reduced to a Residual ARC-c (Column D). Should an operator demonstrate that the local aircraft correspond more to scenarios with a density of 2 or 1, then the ARC level may be lowered to a Residual ARC-b (Column D).

Example 2:

An operator is intending to operate in an airport/heliport environment, in class G airspace, with a corresponding AEC 6.

The operator enters the Initial ARC Reduction table at Row AEC 6. Column A, shows the generalized airspace density rating that corresponds with this environment is 3. Column B shows the associated initial ARC as ARC-c. Column C indicates that if an operator can demonstrate that the actual, local, airspace density corresponds more to a the reference scenario that has a generalized density rating of 1, namely AEC 10, then the Residual ARC level may be reduced to ARC-b (Column D).

Example 3:

Using example 2, the operator could further demonstrate to the competent authority that an UAS operational restriction to fly between 02:00 / 2 AM and 04:00 / 4 AM results in an encounter rate that meets the criteria of Annex G, Section 3.20, then the competent authority may agree to an ARC-a.

Example 4:

An operator is intending to operate below 500 ft. AGL, in a Class G (uncontrolled) airspace, over an urbanized area, with a corresponding AEC 9.

The operator enters the Initial ARC Reduction table at Row AEC 9 Column A indicates that the generalized airspace density rating corresponding with this environment is 2. Column B shows the associated initial ARC is ARC-c. Column C indicates that if an operator demonstrates the local airspace density corresponds more to a density rating of 1, namely AEC 10, then the Residual ARC level may be reduced to ARC-b (Column D).

6.3 Lowering Initial ARC by Common Structures and Rules (optional)

Today, aviation airspace rules and structures mitigate the risk of collision. As airspace risk increases, more structures and rules are implemented to reduce risk. In general, the higher the aircraft density, the higher the collision risk, the more structures and rules are required to reduce collision risk.

Manned aircraft do not use very low level (VLL) airspace 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. ICAO Annex 2, 3.1.2). Subject to permission by the competent authority, and /or ANSP for special flights may be granted permission to use this airspace. Every aircraft will cross VLL-airspace in an airport environment for takeoff and landing.

With the advent of UAS operations, VLL airspace is expected to soon become more crowded, requiring more common structures and rules to lower the collision risk. It is anticipated that UTM/U-space solutions will provide these common structures and rules. This will require mandatory participation by all aircraft in that airspace, similar to how the current flight rules apply to all manned aircraft operating in a particular airspace today.

The SORA does not allow the initial ARC to be lowered through Strategic Mitigation by Common Structures and Rules for all operations above 500ft AGL above VLL; these are AEC 1, 2, 3, 4, 5, and 11.[8] Outside of the scope of the SORA, an operator may appeal to the competent authority and/or ANSP to lower the ARC by Strategic Mitigation by Common Structures. The determination of acceptability falls under normal ANSP airspace rules, regulations and safety requirements.

[8] AEC 1, 2, 3, 4, and 5 already have manned airspace rules and structures, any UAS operating in these airspaces shall comply with applicable ANSP airspace rules, regulations and safety requirements. As such, no ARC lowering by common structures and rules is allowed as those mitigations have already been accounted for in the assessment of those airspaces. Lower ARC for rules and structures in AEC 1, 2, 3, 4, 5, and 11 would amount to double counting of mitigations.

Similarly, the SORA does not allow for lowering the initial ARC through Strategic Mitigation by Common Structures and Rules for all operations in AEC 10.[9]

The maximum amount of ARC reduction through Strategic Mitigation by Common Structures and Rules is one ARC level.

The SORA does allow for lowering the initial ARC through Strategic Mitigation by Structures and Rule for all operations below 500ft AGL, within VLL airspace (AEC 7, 8, 9 and 10)

To claim an ARC reduction, the operator must show the following;

- Equipage of the UA with an Electronic Cooperative system and Anti-Collision Lighting[10]
- 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[11], etc).
- A procedure has been implemented to notify other airspace users of the planned UAS operation (e.g. filing of UAS flight plan, applying for NOTAM from service provider for UAS[12] operations, etc).
- Permission from airspace owner to operate in that airspace has been obtained (if applicable).
- Compliance with the airspace UAS Flight Rules, Regulation, and Policies, etc. applicable to the UAS Operational Volume and to which all/most aircraft are required to comply (these Flight Rules, Regulation, and Policies are aimed primarily at UAS operations in VLL airspace).
- A UAS airspace structure (airways, procedures, airflow management, etc.) exists in VLL airspace to help keep UAS separated from manned aircraft. This structure must be complied with by all UAS.
- 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[13].
- All UAS operators must be able to directly communicate with the Air Traffic Controller or Flight Information Services.

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[9] AEC 10 initial ARC is ARC-b, to lower ARC in these airspaces (to ARC-a) requires the Operational Volume to meet one of the requirements of Atypical/Segregated Airspace.

[10] Although the SORA understands the questionable effects of anti-collision lighting, it also understands that it is low cost to implement, and a net positive in preventing collisions. The SORA does not set airspace rules, we are only encouraging competent authorities and/or ANSP to include anti-collision lighting

[11] Although NOTAMs are used here as an example, the use of NOTAM may not be acceptable unless they cover all operations in VLL airspace. It is envisioned that a separate system like NOTAM, which specifically address the concerns of VLL airspace, will fulfil this requirement.

[12] Although flight plans and posting NOTAMS are used here as an example, the use of flight plans and NOTAM may not be acceptable unless they cover all operations in VLL airspace. It is envisioned that a separate system which specifically address the concerns of VLL airspace will fulfil this requirement.

[13] This refer to possible future applications of automated traffic management separation service for unmanned aircraft in an UTM/U-space environment. These applications may not exist as such today. A subscription to these services may be required.

6.3.1 Demonstration of Strategic Mitigation by Structures and Rules

The operator is responsible to collect and analyze the data required to demonstrate the effectiveness of their Strategic Mitigations by Structures and Rules to the competent authority. Strategic Mitigations by Structures and Rules must be issued by the competent authority, and all aircraft in that airspace must participate for the mitigations to be effective. Showing compliance to Strategic Mitigations by Structures and Rules should be relatively straight forward for the operator.

7 Determination of Residual ARC risk level by the Competent Authority

As stated before, the operator is responsibility to collect and analyze the data required to demonstrate the effectiveness of all their Strategic Mitigations to the competent authority.

The local competent authority and/or ANSP has final determination on the airspace Residual ARC level.

Caution: As the SORA breaks down collision mitigation into Strategic and Tactical parts, there can be overlap between all these mitigations. The operator and competent authority need to be cognizant and assure that mitigations are not double counted.

Although the static generalized risk (i.e. ARC) is conservative, there may be situations where that conservative assessment may be insufficient. In those situations, the competent authority may raise the ARC to a level that is higher than that advocated by the SORA.

For example, an operator surveys a forest near an airport for beetle infestation, the airspace was assessed ARC-b. The airport is hosting an airshow. The competent authority informs the operator that during the week of the airshow, the ARC for that local airspace will be ARC-d. The operator can either equip for ARC-d airspace or suspend operations until the airshow is over.

8 Containment Objective

The expression “loss of containment,” “uncontained,” or “unintentional infringement” refers to failure of the UAS to stay within the approved Operational Volume, with respect to space or time. Section 8 focuses on “loss of containment” by space, as this is the most probable containment objective. However, other containment failures such as proper time, risk of exposure, use of airspace structure, etc., may also need to be addressed.

8.1 Containment Objective Examples

Example 1: The approved UAS Operation Volume is airspace with a Residual ARC of ARC-b. The airspace “adjacent” to the approved Operational Volume is ARC-d, and the airspace overhead is ARC-c. The required compliance levels for OSOs 10 & 12 will be Medium as the adjacent airspace is ARC-d .

Example 2: The approved UAS Operational Volume is in airspace with a Residual ARC of ARC-d. The airspace “adjacent” to the approved Operational Volume is ARC-b and the airspace overhead is ARC-c. OSOs 10 & 12 need not be reconsidered for containment, because the Residual ARC is already ARC-d.

Example 3: The approved UAS Operational Volume is in airspace with a Residual ARC of ARC-b. The airspace “adjacent” to the approved Operational Volume is ARC-d and the airspace overhead is ARC-c. If nothing was done, the operator would have to comply with OSOs 10 & 12 at a Medium level. However, the operator intends to lower the Containment Objective level and reduce the Operational Volume by creating an Air Risk buffer. The competent authority and/or ANSP agree that the Air Risk buffer provides an adequate level of mitigation to reduce the compliance levels for OSOs 10 & 12 to Low.