Joint Authorities for Rulemaking on Unmanned Systems

JARUS guidelines on SORA

Annex B
Integrity and assurance levels for the mitigations used to reduce the intrinsic Ground Risk Class

DOCUMENT IDENTIFIER : JAR-DEL-SRM-SORA-B-2.5

Edition Number	**2.5**
Edition Date	**13.05.2024**
Status	**Release**
Intended for	**Publication**
Category	**Guidelines**
WG	**SRM**

DOCUMENT CHARACTERISTICS

TITLE		
Specific Operations Risk Assessment (SORA) Annex B		
	Publications Reference:	JAR_doc_27
	ID Number:	
Document Identifier	**Edition Number:**	2.5
JAR-DEL-SRM-SORA-B-2.5	**Edition Date:**	13.05.2024
Abstract		
This document describes the requirements for ground risk mitigations based on their robustness.		
Keywords		
SORA, SAIL, Specific, Risk, Ground Risk, Mitigations, Integrity, Assurance		
Contact Person(s)	**Tel**	**Unit**
Jörg Dittrich – DLR / Germany Leader Work Group Safety Risk Management		WG-SRM

STATUS, AUDIENCE AND ACCESSIBILITY					
Status		**Intended for**		**Accessible via**	
Working Draft	□	General Public	☑	Intranet	□
Final	☑	JARUS members	□	Extranet	□
Proposed Issue	□	Restricted	□	Internet (http://jarus-rpas.org)	☑
Released Issue	□	Internal/External consultation □			

DOCUMENT APPROVAL

The following table identifies the process successively approving the present issue of this document before public publication.

PROCESS	NAME AND SIGNATURE WG leader	DATE
WG	Lorenzo Murzilli	27.10.2021
Internal Consultation	Lorenzo Murzilli	27.10.2021
External Consultation	Lorenzo Murzilli	08.11.2022
Publication	Jörg Dittrich	13.05.2024

DOCUMENT CHANGE RECORD

The following table records the complete history of the successive editions of the present document.

EDITION NUMBER	EDITION DATE	REASON FOR CHANGE	PAGES / SECTIONS AFFECTED
1.0	29.01.2018	Version for JARUS Internal Consultation	First edition
1.0	31.05.2018	Version for JARUS External Consultation	Re-work of several sections of the document to account for consultation comments General editing for increased readability
1.0	30.01.2019	Public release	Re-work of several sections of the document to account for consultation comments General editing for increased readability
2.5	27.10.2021	Version for JARUS Internal Consultation	Rework of all sections for clarity and readability. Removal of the Ground Risk Buffer, which has been incorporated into the Main Body and Annex E. Incorporation of VLOS mitigation from the Main Body.
2.5	08.11.2022	Version for JARUS External Consultation	Rework of all sections for clarity. Removal of ERP as a mitigation General editing for increased readability and usability.
2.5	13.05.2024	Public release	Improved clarification of M1(A) and M1(B) to avoid double counting. General editing for improved readability.

DOCUMENT CONTRIBUTORS

WG-SRM Lead	
From December 2022 before December 2022	Jörg Dittrich – DLR / Germany Lorenzo Murzilli – FOCA / Switzerland
Task Force Main Body (including Annexes B, E, I) Co-Leads	
Andreea Perca – FOCA / Switzerland	Tony Nannini - Wing
Annex B Document Lead	
Henri Hohtari -- Wingtra	
Annex B Document Team	
Klavs Andersen – MECK Consult	Romain Bevillard - DGAC
Alberto Cunial - EASA	Alejandro Del Estal - Rigitech
Markus Engelhart - Accenture	Melanie Janin Brusson - DGAC
Tom Putland – CASA / Australia	Dannick Riteco - SORA consulting
Segalite Sellem-Delmar - Safran	

This document was supported by all other members of the responsible Task Force Main Body.

As multiple WG-SRM members have assumed new responsibilities and changed affiliations over the years of document development, all contributors are listed with their affiliation at the time of their last contribution.

CONTENTS

B.1 How to use Annex B

The following table provides the basic principles to consider when using SORA Annex B.

#	Principle description	Additional information
#1	Annex B provides assessment criteria for the integrity (i.e., safety gain) and assurance (i.e., method of proof) of the applicant's proposed mitigations. The proposed mitigations are intended to reduce the intrinsic Ground Risk Class (GRC) associated with a given operation.	The identification and implementation of mitigations is the responsibility of the applicant.
#2	Annex B does not cover the Level of Involvement (LoI) of the Competent Authority. Lol is based on the Competent Authority assessment of the applicant's ability to perform the given operation.	
#3	A proposed mitigation may or may not have a positive effect on reducing the ground risk associated with a given operation. In the case where a mitigation is available but does not reduce the risk on the ground, its level of integrity should be considered equivalent to "None".	
#4	To achieve a given level of integrity/assurance, when more than one criterion exists for that level of integrity/assurance, all applicable criteria need to be met, unless specified otherwise.	If a criterion for a mitigation is not applicable it can be ignored (e.g., passive mitigations do not require training or activation).
#5	Annex B intentionally uses non-prescriptive terms (e.g., suitable, reasonably practicable) to provide flexibility to both the applicant and the Competent Authorities. This does not constrain the applicant in proposing mitigations, nor the Competent Authority in evaluating what is needed on a case-by-case basis.	
#6	This Annex in its entirety also applies to single-person organisations.	
#7	Annex B mitigations are applied to the operational volume and ground risk buffer. Annex B mitigations may be applied to the adjacent area.	Details of mitigation application to adjacent area can be found in Annex F.
#8	All bullet points within all tables in this Annex are meant to be fulfilled unless followed by OR.	
#9	The GRC cannot be lowered to a value less than the equivalent for controlled ground area.	
#10	Any criterion labelled "Technical design" will most likely require the support of the UAS or Component designer for providing declarations and if applicable gathering the required evidence.	Authorities may divide the requirements for different responsible parties in local regulations.
#11	The applicant may claim more points of GRC reduction than indicated in Table 11 (Table 5 in the Main Body), when the appropriate orders of magnitude reduction of the risk to uninvolved people can be demonstrated. Any of these claims should be fulfilled to the high robustness level.	E.g., M2 mitigation can grant the applicant a 3 point reduction of the iGRC, when demonstrating a reduction of 3 orders of magnitude (99.9% reduction) of the risk to uninvolved people.

Table 1 – Basic principles

B.2 M1(A) – Strategic mitigations – Sheltering

M1(A) mitigation is linked to the fact that people spend on average a very small amount of time outdoors unprotected by a structure. Therefore, operators using sufficiently small UAS can expect to have a large percentage of the population sheltered from an impact. This assumption may also apply to larger UAS, in these cases, the sheltering effectiveness should be demonstrated.

Time based arguments such as "I fly at night and there are less people outdoors in my area of operations" do not belong to M1(A) low robustness. At medium robustness time-based arguments are included. Sheltering at low robustness is to be understood as a generally applicable mitigation given by the characteristics of the environment being flown, with no operational restrictions added.

To prevent double counting time-based restrictions, M1(A) medium robustness mitigation cannot be combined with any M1(B) mitigations. However, M1(A) low robustness has no operational restrictions and can be combined with M1(B) mitigations.

		LEVEL of INTEGRITY	
		Low	**Medium**
M1(A) – Sheltering	Criterion #1 (Evaluation of people at risk)	If the applicant claims a reduction due to a sheltered operational environment, the applicant: • flies over operational environments generally consisting of structures providing shelter, • it is reasonable to expect that on average a vast majority of the uninvolved people will be located under a structure[1] This mitigation cannot work when only overflying open-air assemblies of people or areas with no shelter.	Same as low. In addition, the applicant restricts operating times and demonstrates that an even greater proportion of uninvolved people are sheltered.
	Comments	[1] *The consideration of this mitigation may vary based on local conditions. A metastudy of time-activity pattern studies shows that people generally spend at most 10% of their time outside. Diffey, B. (2010). An overview analysis of the time people spend outdoors. The British journal of dermatology. 164. 848-54. 10.1111/j.1365-2133.2010.10165.x.* *The intention is to estimate the proportion of people outside on average and not at a specific time of day or year. There will be times when at specific locations temporarily there are more people exposed, but it should be sufficient to expect that on average the proportion of people exposed outside is below 10%. However, assemblies of people should be avoided. Applicants and/or authorities may consider to adapt this ratio based on other evidence.*	
	Criterion #2 (Evaluation of penetration hazard)	The applicant uses a drone that is not expected to penetrate structures and fatally injure people under the shelter[2].	
	Comments	[2] *Guidance on how to evaluate sheltering effect can be found from:* • *ASSURE UAS Ground Collision Severity Evaluation A4 report section "4.12. Structural Standards for Sheltering (KU)", pages 103 to 111, or* • *MITRE presentation given during the UAS Technical Analysis and Applications Center (TAAC) conference in 2016 titled 'UAS EXCOM Science and Research Panel (SARP) 2016 TAAC Update' - PR 16-3979.* *In general, it can be expected that UAS weighing less than 25 kg are not able to penetrate into buildings except in rare cases where the UAS speed or building materials are unusual (tents, glass roofs, etc). In cases where a UAS is still able to penetrate a structure, sheltering may not be fully effective, but can still offer a partial mitigation.*	

Table 2 - Level of integrity assessment criteria for M1(A) mitigation

		LEVEL of ASSURANCE	
		Low	**Medium**
M1(A) – Sheltering	Criterion #1 (Evaluation of people at risk)	The applicant declares that the operation is in an environment that has structures[1] providing shelter where people are generally expected to be, and the applicant does not fly over large open -air assemblies of people.	Same as Low. In addition, the applicant has time-based restrictions in place and evidence to support that a higher proportion of people are sheltered. Medium robustness M1(A) mitigation cannot be combined with M1(B) mitigations.
	Comments	*[1] For example a city or town consists generally of structures providing shelter. While it may also include areas that are not sheltered, the mitigation is expected to be provided in the majority of such cases.*	
	Criterion #2 (Evaluation of penetration hazard)	The applicant declares that the UA used is under 25 kg MTOM. OR For UA with MTOM higher than 25 kg[1], the applicant has supporting evidence that the required level of integrity is achieved. This is typically done by means of testing, analysis, simulation, inspection, design review or through operational experience.	
	Comments	*[1]UA technical information needed for the evaluation may require support from the UAS designer.*	

Table 3 - Level of assurance assessment criteria for M1(A) mitigation

B.3 M1(B) – Strategic mitigations – Operational restrictions

M1(B) mitigations are intended to reduce the number of people at risk on the ground independently of sheltering. These mitigations are applied pre-flight.
Improvements in static data population density maps are not part of M1(B) mitigation and should be already used in the intrinsic ground risk assessment at Step #2. Use of best available data is encouraged to be used already for the iGRC determination.
An authority may on a case-by-case basis accept pure time exposure arguments for ground risk reduction but should consider how this affects the cumulative risk. M1(B) mitigations are combinations of limitations on time and location of the operation to reduce the number of people at risk at a set time and location.

		LEVEL of INTEGRITY	
		Medium	**High**
M1(B) – Operational restrictions	Criterion #1 (Evaluation of people at risk)	The applicant provides spacetime-based restrictions (e.g., flying over a market square when it is not crowded) to substantiate that the actual density of people during the operation is lower than in Step #2. This can be done by means of: • An analysis or appraisal of characteristics[1] of the location and time[2] of operation, AND/OR • Use of temporal density data (e.g., data from a supplemental data service provider) relevant for the proposed area. This can incorporate real time or historical data.	
	Comments	*[1] Characteristics of the location should be understood as land use that relate to the presence of people, e.g., industrial area, urban park or shopping centres.* *[2] Time should be understood as time of day or day of the week that would influence the presence of people, e.g., weekend for industrial plants, night-time, time after opening hours of shops.*	
	Criterion #2 (Impact on at risk population)	The at-risk population is lowered by at least 1 iGRC population band[3] (~90%) using one or more methods described in the Level of Integrity for Criterion #1 above.	The at-risk population is lowered by at least 2 iGRC population bands[3] (~99%) using one or more methods described in the Level of Integrity for Criterion #1 above.
	Comments	*[3] iGRC population band is described in "3.6.4 – Step #3" of JARUS SORA 2.5 Main body.*	

Table 4 Level of integrity assessment criteria for M1(B) mitigation

		LEVEL of ASSURANCE	
		Medium	**High**
M1(B) – Operational restrictions	Criterion #1 (Evaluation of people at risk)	All mapping products, data sources and processes used to claim lowering the density of population at risk are accepted by the competent authority.	
	Comments	*N/A*	
	Criterion #2 (Impact on at risk population)	The applicant has supporting evidence that the required level of integrity is achieved. This is typically done by means of analysis, simulation, surveys or through operational experience.	The claimed level of integrity is validated by a competent third party against a standard considered adequate by the competent authority and/or in accordance with means of compliance acceptable to that authority.
	Comments	*Quantitative and qualitative mitigations can in combination meet the target reductions of at-risk populations set in medium and high integrity levels.*	

Table 5 Level of assurance assessment criteria for M1(B) mitigation

B.4 M1(C) – Tactical Mitigations – Ground observation

M1(C) mitigation is a tactical mitigation where the remote crew or the system can observe most of the overflown area(s), allowing the detection of uninvolved people in the operational area and manoeuvring the UA, so that the number of uninvolved people overflown during the operation is significantly reduced.

		LEVEL of INTEGRITY
		Low
M1(C) – Ground observation	Criterion #1 (Procedures)	To achieve a reduction of people at risk: • The remote crew members observe the vast majority of the overflown areas during the operation, and identify area(s) of less risk on the ground; • The remote pilot will reduce the number of people at risk by adjusting the flight path while the operation is ongoing (e.g., flying away from the area with a higher risk on the ground or overflying only the identified area(s) of less risk on the ground).
	Comments	*[1] iGRC population band is described in "3.6.4 – Step #3" of JARUS SORA 2.5 Main body.*
	Criterion #2 (Technical means)	If the mitigation is achieved through the use of technical means[1] (e.g., camera(s) mounted on the UA or visual ground observers with radios/phones), these should provide data of sufficient quality allowing reliable detection of uninvolved people on the ground.
	Comments	*[1]Criterion 2 may require support from the UAS or Component designer to gather the required evidences.*

Table 6 - Level of integrity assessment criteria for M1(C) mitigation

		LEVEL of ASSURANCE
		Low
M1(C) – Ground observation	Criterion #1 (Procedures)	The operational procedures for the mitigation are documented. The applicant declares that the required level of integrity has been achieved.
	Comments	*N/A*
	Criterion #2 (Technical means)	Authorities may allow the use of technical means[1] for ground observation with assurance criteria acceptable to them.
	Comments	*[1]Criterion 2 may require support from the UAS or Component designer to gather the required evidences.*

Table 7 - Level of assurance assessment criteria for M1(C) mitigation

B.5 M2 – Effects of UA impact dynamics are reduced

M2 mitigations are intended to reduce the effect of ground impact once the control of the operation is lost. This is done either by reducing the probability of lethality of a UA impact (i.e., energy, impulse, transfer energy dynamics, etc.) and/or by reducing the size of the expected critical area (see table 8 below). Examples include, but are not limited to parachutes, autorotation, frangibility, stalling the aircraft to slow the descent and increase the impact angle. An applicant should demonstrate a required total amount of reduction in either or both factors.

The base assumption in SORA for UAS impact lethality before M2 mitigation is applied is that most[1] impacts are lethal. Based on the characteristic dimensions of an UA, the related critical areas are below displayed in Table 8. Depending on whether the mitigation is passive, manually activated or automatically activated the applicant should provide correspondingly adequate evidence and procedures for a given level of robustness. Reduction of the inherent critical area of a UA by way of analysis should be conducted already in Step #2 of SORA and is not part of M2 mitigation.

Critical area calculations are defined in Annex F, Section 1.8. The SORA Main Body assumes the following critical areas for each characteristic dimension:

Maximum characteristic dimension (m)	1	3	8	20	40
Critical area (m^2)	6.5	65	650	6500	65,000
[1]Note	*Most UA impacts are assumed to be lethal in the SORA ground risk model except:* • *Impacts during slide of UA with characteristic dimension less or equal to 1 m* • *Any impacts during slide of UA with total kinetic energy below 290 Joules* *See Annex F for more details on calculation*				

Table 8 - Critical areas associated with the maximum characteristic dimension (unmitigated)

Applicants claiming for a mitigation by reduction of critical area shall use the values above as the baseline of comparison to show the appropriate mitigation.

If an applicant has used the modifications according to Annex F in Step #2 to show a corrected critical area for their UAS and matched the corrected critical area to a column in Table 8, then this table value is used as the baseline against which the mitigation is assessed.

If an applicant has used the modifications according to Annex F in Step #2 to show both a corrected critical area and matching population density, then this custom critical area value is used as the baseline against which the mitigation is assessed, and the custom population density value must be used as a limitation in the operation.

		LEVEL of INTEGRITY	
		Medium	**High**
M2 – Effects of UA impact dynamics are reduced	Criterion #1 (Technical design)	• Effects of impact dynamics and immediate post impact hazards[1], critical area or the combination of these results are reduced such that the risk to population is reduced by an approximate 1 order of magnitude (90%)[2,3]. • When applicable, in case of malfunctions, failures or any combinations thereof that may lead to a crash, the UAS contains all elements required for the activation of the mitigation[4]. • When applicable, any failure or malfunction of the proposed mitigation itself (e.g., inadvertent activation) does not adversely affect the safety of the operation.	Same as Medium. In addition: • When applicable, the activation of the mitigation is automated[4, 5, 6]. • The effects of impact dynamics and immediate post impact hazards[1], critical area or the combination of them are reduced such that the risk to the population is reduced by an approximate 2 orders of magnitude (99%)[2,3].
	Comments	*[1] Examples of immediate post impact hazards include fires and release of high energy parts.* *[2] Latest research on UAS impacts estimate injuries using the Abbreviated Injury Scale (AIS) developed for automotive impact tests and test dummies. An impact that has a 30% chance of causing injury of AIS level 3 injury or greater is estimated to have a 10% probability of death. Note that the SORA methodology only considers fatalities. It does not provide guidance on the injury levels / thresholds beyond which an injury should be considered as a fatality. Further Guidance on how to evaluate impact severity measurement may be found for example in Ranges of Injury Risk Associated with Impact from Unmanned Aircraft Systems DOI: 10.1007/s10439-017-1921-6, ASSURE UAS reports A14 and A4 on UAS Ground Collision Severity Evaluation.* *[3] The reduction in risk detailed here is equivalent to a "System Risk Ratio" which requires that the combination of functional performance (i.e., the reduction in risk when the mitigation functions as intended) and reliability (i.e., the chance that the mitigation does not function as intended) combined meet the requirement.* *[4] No single failure should lead simultaneously to a loss of control of the operation and loss of the effectiveness of the M2 mitigation.* *[5] An automated activation may be required when reaction time is critical or the operator cannot determine the need for activation.* *[6] The applicant may nevertheless implement an additional manual activation function.*	
	Criterion #2 (Procedures)	Any equipment used to reduce the effect of the UA impact dynamics are installed and maintained in accordance with UAS/Mitigation designer instructions.	
	Comments	*N/A*	
	Criterion #3 (Training)	When use of the mitigation requires action from the remote crew, then appropriate training must be provided for the remote crew by the operator. The operator must ensure that the personnel responsible (internal or external) for the installation and maintenance of the mitigation measures are qualified for the task.	
	Comments	*N/A*	

Table 9 - Level of Integrity Assessment Criteria for M2 mitigation

		LEVEL of ASSURANCE	
		Medium	**High**
M2 – Effects of UA impact dynamics are reduced	Criterion #1 (Technical design)	The applicant has supporting evidence to claim the required level of integrity and reliability is achieved[1]. This is typically done by means of testing, analysis, simulation[2], inspection, design review or through operational experience. A UAS with MTOM lower or equal to 900g and a maximum speed of 19 m/s fulfils this assurance Criteria 1.	The claimed level of integrity is validated by a competent third party against a standard considered adequate by the competent authority and/or in accordance with means of compliance acceptable to that authority[3] (when applicable).
	Comments	*1 The use of Industry standards such as prEN 4709-001, ASTM F3389/F3389M-21 and F3322-18 is encouraged when developing mitigations used to reduce the effect of ground impact.* *2 When a simulation is used, the validity of the targeted environment used in the simulation needs to be justified.* *3 Competent Authorities (CAs) may define the standards and/or the means of compliance they consider adequate. The SORA Annex B will be updated at a later point in time with a list of adequate standards based on the feedback provided by the CAs.*	

	Criterion #2 (Procedures)	• Procedures are validated against standards considered adequate by the competent authority and/or in accordance with means of compliance acceptable to that authority[4].
		• The adequacy of the procedures is proved through:
		  ○ Dedicated flight tests, or
		  ○ Simulation, provided that the representativeness of the simulation means is proven for the intended purpose with positive results.
			Same as Medium. In addition:
			• Flight tests performed to validate the procedures cover the complete flight envelope or are proven to be conservative.
			• The procedures, flight tests and simulations are validated by a competent third party.

	Comments	*[4] Competent Authorities (CAs) may define the standards and/or the means of compliance they consider adequate. The SORA Annex B will be updated at a later point in time with a list of adequate standards based on the feedback provided by the CAs.*	
	Criterion #3 (Training)	• Training syllabus is available. • The operator provides theoretical and practical training for the remote crew. • Personnel responsible for installation and maintenance of the mitigation measures have completed relevant training.	Same as Medium. In addition, a competent third party: • validates the training syllabus. • Verifies the remote crew competencies
	Comments	*N/A*	

Table 10 - Level of Assurance Assessment Criteria for M2 mitigation

B.6 Mitigations effects table for determining the final GRC

Ground risk mitigation	Level of Robustness		
	Low	Medium	High
M1(A) – Strategic mitigations - Sheltering	-1	-2	N/A
M1(B) – Strategic mitigation – Operational restrictions	N/A	-1	-2
M1(C) – Tactical mitigations – Ground observation	-1	N/A	N/A
M2 – Effects of UA impact dynamics are reduced	N/A	-1	-2

Table 11 - Mitigations effect for final GRC determination