JARUS	**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

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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. LoI is based on the Competent Authority assessment of the applicant's ability to perform the given operation.	Some JARUS groups might provide criteria for level of involvement for use by the Competent Authorities.
#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.	
#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 organizations.	
#7	Annex B mitigations are applied to the Operational volume and Ground risk buffer.	
#8	All bullet points within all tables in this Annex are meant to be fulfilled unless followed by OR.	In case a table includes AND/OR in the Integrity criteria this means that a combination of different methods may be used to meet the required total level of performance.

Table 1 - Basic Principles

2. M1(A) – Strategic mitigations for ground risk

M1(A) mitigations are "strategic mitigations" intended to reduce the number of people at risk on the ground. Because of their strategic nature, these mitigations are applied pre-flight during the planning phase. To assess integrity levels of M1 mitigations the following needs to be considered:

- Population density overflown,
- Evaluation of people at risk.

Improvements in static data population density maps are not part of M1(A) mitigation, but should be already used in the intrinsic ground risk assessment at Step #2. Use of best possible data is encouraged but it should be used already for the iGRC determination.

An authority may accept time exposure arguments for ground risk reduction, but should understand how this affects the cumulative risk. Annex F chapter "Short Exposure Flight Over Higher Population Segments" has additional information on the matter.

The criteria to assess the level of integrity and level of assurance of M1(A) type ground risk mitigations are provided respectively in Tables 2 and 3.

		LEVEL of INTEGRITY		
		Low	**Medium**	**High**
M1(A) – Strategic Mitigations for Ground Risk	Criterion #1 (Evaluation of people at risk)	The applicant evaluates the area of operations by means of appraisals/on-site inspections to justify lowering the density of population at risk (e.g. residential area during daytime when some people may not be present or an industrial area at night time for the same reason). Increased accuracy static population density maps should not be used as a mitigation, but as the baseline in Step #2. AND/OR If the applicant claims a reduction, due to a sheltered operational environment, the applicant: • uses a drone that is not expected to penetrate structures under which people are sheltered[1], • it is reasonable to consider that most of the non-active participants will be located under a structure[2]. Low robustness for sheltering is achieved for operators of most small UAS[1] by citing a study[2], while avoiding flights next to large gatherings of people ~20,000 ppl or more. AND/OR The applicant makes use of dynamic density data (e.g. data from UTM supplemental data service provider) relevant for the proposed area and restricts time of operation to substantiate a lower density of population at risk. This can incorporate real time or historical data or dasymetric mapping techniques that are not part of standard maps used for Step #2.		
	Comments	*[1] 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 25kg 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 perfect, but can still offer an amount of mitigation.* *[2] The consideration of this mitigation may vary based on local conditions. A metastudy of time-activity pattern studies shows that people generally spend less than 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.*		
	Criterion #2 (Impact on at risk population)	The at-risk population is lowered by at least 1 iGRC population band (~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 (~99%) using one or more methods described in the Level of Integrity for Criterion #1 above.	The at-risk population is be lowered by at least 3 iGRC population bands (~99.9%) using one or more methods described in the Level of Integrity for Criterion #1 above.
	Comments	*N/A*	*N/A*	*N/A*

41 ***Table 2 - Level of Integrity Assessment Criteria for Ground Risk M1(A) Mitigations***

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		LEVEL of ASSURANCE		
		Low	**Medium**	**High**
M1(A) – Strategic Mitigations for Ground Risk	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/approved by the competent authority.		
		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 testing, analysis, simulation, inspection, design review or through operational experience.		A competent third party validates the claimed level of integrity.
	Comments	*Quantitative and qualitative mitigations should in combination meet the target reductions of at risk populations set in Low, Medium and High integrity levels.*		

43 ***Table 3 – Level of Assurance Assessment Criteria for Ground Risk M1(A) Mitigations***

3. M1(B) – Visual Line of Sight (VLOS) - avoid flying over people

M1(B) mitigation is a tactical mitigation where the remote pilot has good visibility around him to the surrounding ground areas and the pilot is avoiding flying above any people. Assuming good visibility on the ground for the operational volume, it is expected that most VLOS operations can achieve Low robustness for M1(B) mitigation.

		LEVEL of INTEGRITY
		Low
M1(B) - Visual Line of Sight (VLOS) - avoid flying over people	Criterion 1	• The operation is performed within Visual Line of Sight (VLOS) of the remote pilot. • While operating the drone, the remote pilot can safely and unambiguously identify area(s) of less risk on the ground. • The remote pilot is able to safely reduce the number of people at risk by: ○ Flying at a safe distance[1] from non-active participants OR; ○ In an abnormal situation: - being still able to command or manoeuvre the drone to a less populated area; OR - having the ability to alert or notify people near the drone to get to safety.
	Comments	*[1] As defined by the competent authority or at least using a horizontal distance derived from a 1:1 principle*

Table 4 - Level of Integrity Assessment Criteria for Ground Risk M1(B) Mitigations

		LEVEL of ASSURANCE
		Low
M1(B) - Visual Line of Sight (VLOS) - avoid flying over people	Criterion 1	The operational procedures for the mitigation are documented, including the safe distance from non-active participants (when applicable).
	Comments	*N/A*

Table 5 - Level of Assurance Assessment Criteria for Ground Risk M1(B) Mitigations

4. M2 – Effects of ground impact are reduced

M2 Mitigations are intended to reduce the effect of ground impact once the control of the operation is lost. This is done by either reducing the probability of lethality of a UA impact (i.e. energy, impulse, transfer energy dynamics, etc.) and/or reducing the size of the expected critical area*. Examples include, but are not limited to: parachutes, autorotation, frangibility, stalling the aircraft to slow the descent and increase the impact angle.

The base assumption in SORA for UAS impact lethality before M2 mitigation is applied is that all impacts are lethal and the critical areas for impacts correspond to the following table. An applicant should demonstrate a required total amount of reduction in either or both of these factors. Depending on whether the mitigation is passive, manually activated or automatically activated the applicant must produce 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.

* Critical area calculations are defined in Annex F. 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)	8	135	1,350	13,500	135,000

Applicants arguing 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 a different critical area via the modifications in Annex F for their UAS then that value should be used as the baseline against which the mitigation is assessed.

		LEVEL of INTEGRITY		
		None	**Medium**	**High / High+**
M2 - Effects of UA impact dynamics are reduced	Criterion #1 (Technical design)	N/A	• 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]. • 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.	High Same as Medium. In addition: • When applicable, the activation of the mitigation is automated[3]. • 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].

			• When applicable, any failure or malfunction of the proposed mitigation itself (e.g. inadvertent activation) does not adversely affect the safety of the operation.[3]	High+ Same as above. In addition: • 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 3 orders of magnitude (99.9%)[2].
	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 injury of AIS level 3 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] *Failures or malfunctions of the UAS or mitigation means should not prevent the safe functioning of either system independently if applicable.*		
		N/A	*N/A*	[4] *The applicant retains the discretion to implement an additional manual activation function.*
	Criterion #2 (Procedures, if applicable)	Any equipment used to reduce the effect of the UA impact dynamics are installed and maintained in accordance with manufacturer instructions.[5]		
	Comments	[5] *The distinction between a low, a medium and a high level of robustness for this criterion is achieved through the level of assurance (Table 7 below).*		
	Criterion #3 (Training, if applicable)	When use of the mitigation requires action from the remote crew, then training must be provided for the remote crew by the operator. If personnel responsible for the installation and maintenance of the mitigation measures are internal to the operator, then these personnel must be identified and provided training by the operator.[6]		
	Comments	[6] *The distinction between a low, a medium and a high level of robustness for this criterion is achieved through the level of assurance (Table 7 below).*		

74 ***Table 6 - Level of Integrity Assessment Criteria for M2 Mitigations***

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		LEVEL of ASSURANCE		
		Low	**Medium**	**High / High+**
M2 - Effects of UA impact dynamics are reduced	Criterion #1 (Technical design)	N/A	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.	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	*N/A*	*[1] The use of Industry standards 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] National Aviation Authorities (NAAs) 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 NAAs.*

	Criterion #2 (Procedures, if applicable)	N/A	• 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.

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	Comments	*[4] National Aviation Authorities (NAAs) 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 NAAs.*		
	Criterion #3 (Training, if applicable)	N/A	• Training syllabus is available. • The Operator provides competency-based, theoretical and practical training.	• Training syllabus is validated by a competent third party. • Competencies are verified by a competent third party.
	Comments	*N/A*	*N/A*	*N/A*

76 ***Table 7 - Level of Assurance Assessment Criteria for M2 Mitigations***