MIL-UAS-SPECIFIC: Methodology update

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ID	*Title*	*No./Author*	*Issuing date (dd/mm/yyyy)*	*Issued by*
[RD1]	Risk Assessment Tool	RAT	2017	EDA ARF WG
[RD2]	Proposed Risk Assessment Tool	pRAT	2021	Portugal NMAA
[RD3]	Technical Instructions for the Safe Transport of Dangerous Goods by Air	Doc 9284, 2021-2022 Edition, including Addendum 2	23/02/2021	ICAO
[RD4]	Convention on International Civil Aviation (Chicago Convention)	Doc 7300/9, 9th edition	2006	ICAO
[RD5]	UAS traffic management (UTM) — Part 12:	ISO FDIS 23629-12	21/01/2022	ISO

	Requirements for UTM service providers			
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ACRONYMS

Acronym	***Description***
A/C	Aircraft
ACA	Airspace Control Authority
ADC	Air Defence Controller
ACP	Airspace Control Plan
AEH	Airborne Electronic Hardware
AFIU	Aerodrome Flight Information Unit
AGL	Above Ground Level
AIP	Aeronautical Information Publication
AMC	Acceptable Means of Compliance
ANSP	Air Navigation Service Provider
ARMS	Air Risk Mitigation Score
ATC	Air Traffic Control
ATO	Air Task Order
ATS	Air Traffic Services
AWY	Airway
BRLOS	Beyond Radio Line Of Sight
BVLOS	Beyond Visual Line Of Sight
C2 link	Command and Control link
CAC	Containment Assessment Checklist
CRM	Crew Resource Management
CS	Containment Score
CTA	Control Area
CTR	Control Zone
DAA	Detect-And-Avoid
DIAC	Design and Integrity Assessment Checklist
DIS	Design and Integrity Score

DMA	Dynamic Mobile Area
DMOD	Distance Modification
E3	Electromagnetic Environmental Effects
EASA	European Union Aviation Safety Agency
EC	European Commission
EDA	European Defence Agency
EDA pMS	EDA participating Member States
EMI	Electromagnetic Interference
EUSC	EuroUSC Italia S.r.l.
EVLOS	Extended Visual Line Of Sight
FTA	Fault Tree Analysis
GAT	General Air Traffic
HIRF	High-Intensity Radiated Fields
HMD	Horizontal Modification
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
JARUS	Joint Authorities for Rulemaking on Unmanned Systems
LEO	Leonardo S.p.A.
MAA	Military Aviation Authority
MAC	Mid-Air-Collision
MDAC	Minimum Detect-And-Avoid Requirements Checklist
MDAR	Minimum Detect-And-Avoid Requirements
MDARC	Minimum Detect-And-Avoid Requirements Checklist
MIL	Military
MTOM	Maximum Take-Off Mass
MTOW	Maximum Take-Off Weight
OPU	(military UAS) Operational Unit
MUSRA	MIL-UAS-SPECIFIC Risk Assessment
MUSRAT	MIL-UAS-SPECIFIC Risk Assessment Tool
NMAA	National Military Airworthiness Authorities
NOTAM	Notice To AirMen
pMS	The participating Member States
pRAT	proposed Risk Assessment Tool

RA	Risk Assessment
RADAR	Radio Detection And Ranging
RAT	Risk Assessment Tool
RCS	Required Containment Score
RDIS	Required Design and Integrity Score
RFC	Remote Flight Crew
RP	Remote Pilot
RPAS	Remotely Piloted Aircraft Systems
RR	Risk Ratio
RSSI	Received Signal Strength Indicator
RTH	Return-To-Home
SAA	See And Avoid
SARP	(ICAO) Standards and Recommended Practice
SORA	Specific Operations Risk Assessment
SW	Software
TCR	Traffic Conflict Risk
TEC	Traffic Encounter Category
TIS	Traffic Information Service
TLS	Target Level of Safety
TMA	Terminal Area
TRA	Temporary Reserved Area
TSA	Temporary Segregated Area
UA	Unmanned Aircraft
UAS	Unmanned Aircraft Systems
UCS	Unmanned Control Station
USSP	U-Space Service Provider
UTM	UAS Traffic Management
VLOS	Visual Line Of Sight
WG	Working Group
WP	Working Paper

Terms and definitions

Word	***Description***
Adjacent Airspace	The airspace adjacent to the Operational Volume
Adjacent area/airspace	The ground area/airspace adjacent to the Ground/Air Risk Buffer. The extent of the adjacent area depends on the particular UA performance and the resulting likelihood of flying into an area with an increased level of risk.
Aerodrome environment	The region surrounding an airport or heliport in which arriving and departing manned aircraft typically fly. The airport environment is defined by the Authority having jurisdiction over the involved airspace and/or the relevant ANSP.
BRLOS	BRLOS refers to any configuration in which the transmitters and receivers are not in RLOS. BRLOS thus includes all satellite systems and possibly any system where a UCS communicates with one or more radio ground stations via a terrestrial network, to maintain a connection with a UA in flight. This communication architecture leads to a higher latency in comparison to an RLOS system.
Contingency volume	The volume outside the flight geography where contingency procedures are used to regain full control of the UAS. E.g. the volume within which the UAS may fly during a temporary loss of the C2 link.
Cross-border operations	Operations that are established over national borders between two States (possibly in a restricted or reserved volume of airspace), or UAS operations within the borders of a foreign country.
Dangerous goods	Dangerous goods are 'articles or substances, which are capable of posing a hazard to health, safety, property or the environment', which appear on the list of dangerous goods of the ICAO Technical Instructions for the Safe Transport of Dangerous Goods by Air (ICAO Doc 9284) [RD3].
Due regard	The contracting States undertake, when issuing regulations for their state aircraft, that they will have due regard for the safety of navigation of civil aircraft. (ICAO CC Art 3d)) [RD4]
Encounter rate	The rate at which an aircraft could encounter another aircraft in a given airspace volume. The encounter rate grows exponentially by the number of aircraft within a defined airspace volume. The more aircraft are within the airspace volume the higher the encounter rate.
Flight geography	The volume within which the UAS mission is planned. Flight geography should be defined considering the overall accuracy in the UAS positioning, i.e. the Total System Error (TSE)
Operational volume	The combination of the flight geography and contingency volume
RLOS	RLOS refers to the situation in which the transmitter(s) and receiver(s) are within mutual radio link coverage and thus able to provide direct communications between the UA and the UCS
Target Level of Safety (TLS)	The TLS is the "safety goal of an oversight authority, an operator, or a service provider. It provides the minimum safety objective(s) acceptable to the oversight authority and to be achieved by the operators/service providers while conducting their core business functions." (ICAO Annex 11, Attachment E).
U-space (alias UTM)	Set of traffic management and air navigation services (ANS) aiming at safe, secure, and efficient integration of multiple manned and unmanned aircraft flying inside the respective Designated Operational Coverage of each service (ISO 23629-12) [RD5]

WRT	With Regard To

1 INTRODUCTION

1.1 Background

The MIL-UAS-SPECIFIC Risk Assessment (MUSRA) methodology was developed considering the inputs received in the first phase of the project from EDA pMS (EDA participating Member States). The methodology considers the perspective of the National Military Airworthiness Authorities (NMAAs) and the military UAS operators. The Ground and Air risk models supporting the Risk Assessment process do not vary depending on the "user" but the order of the steps and the inputs and outputs are adapted to the specific user's needs.

The Ground Risk model takes RAT (Risk Assessment Tool) [RD1] and the version proposed by Portuguese NMAA pRAT (proposed Risk Assessment Tool) [RD2] as the baseline and integrates it by:

a. Reviewing the Design and Integrity Checklist's applicability to different UAS (Unmanned Aircraft System) designs
b. Adding considerations about risk related to the carriage of dangerous payloads for the definition of the minimum required RAT score.
c. Adding requirements to ensure the mission is contained in the operational volume.
d. Adding the evaluation of the operator's organisation, the personnel competencies, and the presence of critical infrastructures as contributing factors to the definition of the score.

The Air Risk model is inspired by the Specific Operations Risk Assessment (SORA) developed by the Joint Authorities for Rulemaking on Unmanned Systems (JARUS) as transposed by EASA in AMC1 to Art. 11 of EU Reg. 2019/947 [RD10] but adapted to consider military specificities, such as:

a. An airspace categorisation that considers typical military scenarios
b. Risk related to simultaneous operations of several UAS (e.g. risk of collision, risk of C2 Link interference) in the same operational volume.
c. The needs to complement the evaluation from the operator's perspective with the one from the airspace regulating and managing entities.

The first version of the methodology was released in May 2022 [ref. D2 – MIL-UAS-SPECIFIC: methodology) and applied to selected use-cases in July 2022 [ref. D3 – MIL-UAS-SPECIFIC: guidance). Based on the experience gained and the preliminary feedback received by EDA pMS an updated version has been developed and included in this document to be used for an extensive validation campaign involving EDA pMS.

1.2 Structure of the document

This document breaks down into 2 chapters and 4 Annexes as follows:

- ***Chapter 1 "Introduction":*** Contains an overview of the content of this deliverable, explaining the background of the MUSRA methodology and the roles and responsibilities involved in the MUSRA development process.
- ***Chapter 2 "MIL-UAS-SPECIFIC RA Methodology***": Describes the MUSRA process and how it shall be carried out by two different users: the NMAA and the Operational Unit (OPU). Depending on the user, different steps in the MUSRA process are applicable.
- ***Annex A "Ground Risk Model"***: contains the description of the model supporting the determination of the Ground Risk.
- ***Annex B "Air Risk Model":*** contains the description of the model supporting the determination of the Air Risk.

- ***Annex C "Score Computation":*** contains the description of the checklists and questionnaires that the user must complete to compute the score associated to a given UAS and/or mission.
- ***Annex D "Additional guidance":*** contains additional guidance to carry out specific steps of the methodology

1.3 Applicability

MIL-UAS-SPECIFIC Risk Assessment methodology aims at guiding the UAS Operational Unit and the military competent authorities in evaluating the safety risks of the operation of Unmanned Aircraft systems of any class and size operated in the MIL-UAS-SPECIFIC category of operations.

Safety risks associated with collisions between UA and manned aircraft are in the scope of the methodology, which is also suitable to assess the risk of Mid-Air Collision (MAC) for operations in non-segregated airspace.

Operations involving the carriage of people are instead excluded from the applicability of MUSRA.

Additional limits in the applicability of the methodology can emerge during the Risk Assessment process if the operating scenario exceeds the acceptable level of risk defined by the NMAA. For example, it may not be possible, using this methodology, to demonstrate that the flight of a UA with an MTOM of 900kg is safe if it takes place over an area with a population density of 1000 people/km^2. In fact MUSRA is suitable to assess the risk of operations in which the maximum allowable probability of having a catastrophic failure is 1E-4/FH or higher. If the required probability of catastrophic failure needs to be lower, the UAS will need to undertake a full certification process even though the operation can still be classified in the MIL-UAS-SPECIFIC category depending on national specificities. In this case MUSRA may still be used but the process presented in this document would require some adaptations to consider that the UAS holds a Type Certificate.

MUSRA is limited to the assessment of operations with a required probability of having a catastrophic failure of 1E-4/FH or higher because this is the limit used by RAT that is one of the main references. Moreover, this limit is consistent with the approach that is used in the civil sector. In fact EASA recommends that for operations classified with a SAIL of III and IV, corresponding to a probability of operation out of control[4] respectively of 10E-3/FH and 1E-4/FH, the UAS undergoes a Design Verification Process, while for SAIL V and VI a full type certification is required.

1.4 Roles and responsibilities

The MUSRA process requires the interaction of several actors. In particular, the following (not exhaustive) are identified as the main users and contributors to the development of the Risk Assessment.

a. *National Military Airworthiness Authority (NMAA)*: The NMAA is the authority responsible for verifying that the UAS design and integrity characteristics are adequate for its intended use. The NMAA will apply the MUSRA process to a given UAS to evaluate its design and integrity characteristics upon receiving a request from an Operational Unit or another relevant entity. To facilitate the introduction of new platforms the NMAA can also use MUSRA to determine the scenario in which a given UAS can be operated safely within the MIL-UAS-SPECIFIC category (i.e. without requiring a full airworthiness certification). The information required to assess the UAS will be provided by the Operational Unit that will likely need to work closely with the manufacturer of the UAS and/or the manufacturer(s) of its components. The verification process can be supported by other entities that can be involved in relation to their respective competences/responsibilities and depending on national specificities (e.g. Airspace Managing Authorities)

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[4] The concept of "operation out of control" used in SORA is equivalent to "proability of catastrophic failure" in MUSRA.

b. *Operational Unit (OPU)*: The Operational Unit can use the MUSRA process to check if the planned mission can be carried out safely using a given UAS. If the UAS selected has already undergone the verification process from the NMAA, the OPU will only verify that the intended operating conditions, the organisational structure, and the personnel competencies would properly support the safety of the mission. If the UAS design and integrity has not been verified by the NMAA, the OPU, with the support of the manufacturer, would need to apply to the competent NMAA to get the Risk Assessment and the UAS design verified. This process is expected to apply especially to cross-border operations.
c. *UAS Manufacturer/Designer*: The UAS manufacturer is the party that designs and manufactures the UAS. The manufacturer/designer possesses all the evidence related to system performance, system architecture, software/hardware development documentation, test/analysis documentation, etc. that are needed by the NMAA to verify the design and integrity of the UAS. The UAS manufacturer/designer will thus need to support the OPU to carry out the MUSRA process and submit all the required evidence to the NMAA.
d. *Component Manufacturer*: The component manufacturer is the party that designs and manufactures components for use in UAS operations. Like the UAS manufacturer, the component manufacturer possesses all the evidence that is needed by the NMAA to verify the design and integrity of a given component. Examples of components that may not be directly designed by the UAS manufacturer/designer are: Detect-And-Avoid, Payloads, etc.
e. *Competent Authority (COA)*: this is the military entity responsible for setting Target Levels of Safety (TLS) at a national level. In addition, this entity can be responsible for carrying out airspace characterisation studies to define in a more accurate way the level of risk of different airspace categories considering the air traffic density and the availability of safety-relevant services (e.g. ATC, U-space). In some EDA pMS the above responsibilities may be shared among different actors including e.g. a military airspace authority.

2 MIL-UAS-SPECIFIC RA Methodology

This chapter describes the MUSRA process considering both the NMAA and the OPU perspectives. Additional details on how to carry out the individual steps and the Ground and Air risk models are provided in Annex.

2.1 Process outline

The process chart below shows an overview of the three different paths (yellow for the NMAA, green for the OPU, and blue for the UAS manufacturer/designer/component manufacturer) foreseen by the MUSRA process.

Both the yellow and green paths share the same "Step #0 – Definition of acceptable P_{kill}" which is carried out at pMS level before the actual Risk Assessment process starts.

The individual steps are described in the following sections.

The ***NMAA path*** is divided into three main steps:

- Step #A: Data verification
- Step #B: Score computation
- Step #C: Scenario definition (optional)

The ***OPU path*** is divided into three main steps:

- Step #1: Scenario description
- Step #2: Required score computation
- Step #3: UAS selection and score correction

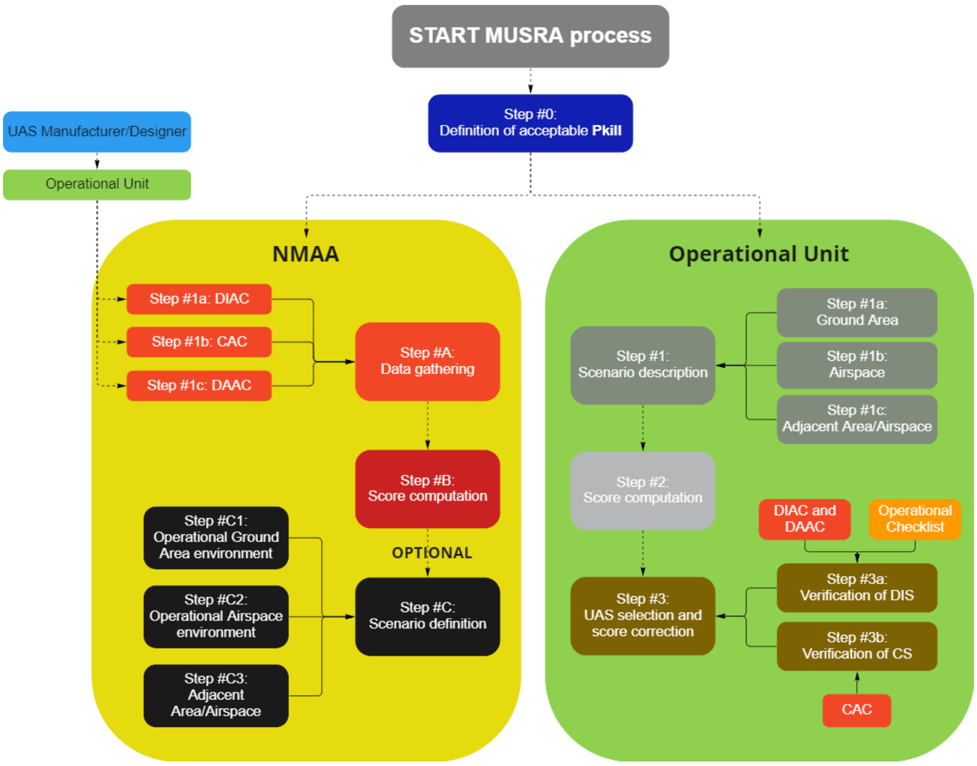

Figure 1: MUSRA process chart

2.2 Step #0 Definition of acceptable probability of causing fatalities (P_{kill})

This preliminary step is intended for each pMS to determine which is the acceptable TLS. In the context of MUSRA the TLS is considered the maximum acceptable probability of causing fatalities both on the ground and in the air (P_{kill}). TLS is defined by ICAO as "The acceptable level of safety expresses the safety goals of an oversight authority, an operator, or a services provider. From the perspective of the relationship between oversight authorities and operators/services providers, it provides the minimum safety objective(s) acceptable to the oversight authority to be achieved by the operators/services providers while conducting their core business functions." (ICAO Annex 11, Attachment E). In other terms TLS can be defined as a quantified risk level, measured as the fatality rate caused by the operation of a system and it is determined by analysing historical traffic data in different operating conditions. Reference values for UAS can be taken from JARUS AMC.RPAS.1309 issue 2 [RD40] where a TLS of 10^{-4}/FH is quoted for UAS equivalent to manned CS-23 Class I aircraft, and a TLS of 10^{-6}/FH is quoted for UAS equivalent to commercial large aeroplanes. These TLS refer to the probability of causing a fatal accident because of a crash. However, if we refer to the TLS for mid-air-collisions (MAC), the reference values are 10^{-9}/FH for commercial aircraft and 10^{-6}/FH for general aviation [RD41]. Since a single TLS is needed to determine the maximum probability of catastrophic failure for the UAS and the resulting technical requirements, a value of 10^{-6}/FH can be selected to be in line with the civil general aviation TLS. However, pMS can decide to relax this constraint if needed.

This step is carried out before the actual risk assessment process is initiated by either the NMAA or the operational unit.

2.3 The NMAA process

The NMAA will use the MUSRA methodology to assess the design characteristics of a given UAS and possibly determine the scenario in which it can be safely operated. In this context, the MUSRA methodology provides an alternative mean to the usual UAS type certification process.

2.3.1 Step #A: Data verification

The first step of the process is intended to gather data about the design characteristics of the UAS, its containment system and any equipment that contributes to the safety of the operation. The NMAA is expected to receive all required information from the OPU which provides an application to get a UAS design verified. The manufacturer of the UAS and/or its components will work in close cooperation with the OPU to provide the required information and data. Three different questionnaires need to be completed by the manufacturer and verified by the NMAA, namely:

1. Design and Integrity Assessment Checklist (DIAC): this is the questionnaire used to gather information about the design and integrity characteristics of the UAS. Answers should include references to evidence that the requirements are fulfilled.
2. Containment Assessment Checklist (CAC): this questionnaire is used to evaluate the reliability of the containment system intended to avoid the UAS flying outside the operational volume in an adjacent area with different characteristics from both the ground and air risk perspectives.
3. Minimum Detect-And-Avoid Requirements Checklist (MDARC): MUSRA assumes that a DAA capability is required to fly in non-segregated airspace. If this capability is provided onboard the UAS, the MDARC is used to evaluate the technical characteristics of such a system. If this capability is provided by external services (e.g. Ground-based radar, U-space) that are not under the control of the UAS manufacturer, application of the MDARC is optional.

2.3.1.1 The Design and Integrity Assessment Checklist (DIAC)

The DIAC proposed by MIL-UAS-SPECIFIC uses the one included in pRAT [RD2] and integrates it with additional references to industry standards. STANAG 4703 remains the main reference, but the questionnaire was revised to make it applicable also to UAS that are developed according to STANAG 4671 and STANAG 4702. The DIAC is used to define the *Design and Integrity Score (DIS)* that is used in Step #B to compute the probability of catastrophic failure (P_{cat}). DIAC is made of several questions and evaluation criteria, to be demonstrated by documentation or proof (i.e. Evidence), related to **11 areas**:

1. Organisation / Manufacturer.
2. Adopted Design Standards.
3. Tested Usage Spectrum.
4. Stability, Control, Navigation performance and Emergencies.
5. UAS (Remote) Control Station.
6. Structural Integrity.
7. Propulsion and Feeding System Integrity.
8. The integrity of Systems and Equipment.
9. Safety Demonstration.
10. Software Integrity.
11. Continued Airworthiness and Operational Suitability.

The updated DIAC can be found in Annex C.1.1.

Design and Integrity score (DIS): This score is initially computed by evaluating the responses to the DIAC for each domain. The score is the sum of the initial scores per each domain:

$$Total\ Score = \sum (Domain\ Score)_i$$

The maximum value that can be obtained is 100. A **correction factor matrix** is then established to reduce the score of specific domains with cross-domain items whose absence will harm the reliability of that domain (see Annex C.1.2). Finally, additional penalties may further reduce the score if some of the mandatory requirements are not properly fulfilled. This score is linked to the probability of having a catastrophic failure (P_{cat}).

2.3.1.2 The Containment Assessment Checklist (CAC)

The CAC aims to analyse the effectiveness of the containment system to limit the probability of the UA leaving the operational volume intended for the operation. The CAC with the related evidence is used to define a *Containment Score (CS)* based on the performance of the containment system for the UAS under assessment. This score is then used in step #B to compute the Probability for the UA to exit the operational volume (P_{exit}). CAC can be found in Annex C.3.1.

2.3.1.3 Minimum Detect-And-Avoid Requirements Checklist (MDARC)

MDARC gathers information on design integrity and performance characteristics of the Detect-And-Avoid system on board the UAS under assessment, if available. The MUSRA Air Risk Model (ANNEX B) assumes that a DAA capability is required to fly in non-segregated airspace. The required performance of the DAA will vary depending on the Air Risk that is associated with the airspace where the flight takes place. The required level of performance can be achieved with different architectures and technical solutions relying on onboard or external functionalities. The MDARC covers all possibilities, but in this step, the NMAA in collaboration with other relevant entities (e.g. Airspace Managing Authorities) should only verify the performances of any onboard capabilities, if available. Additional DAA capabilities provided by e.g. external services are considered in the OPU process (see section 2.4.1.2). Overall, the combination of onboard and external DAA capabilities must be adequate to fly safely in each airspace. MDARC is presented in Annex C.5.

2.3.2 Step #B: Score computation

This step is intended to compute a score that provides a measurement of the reliability of the UAS design and the containment system. In particular, two elements are computed:

a. **Probability of having a catastrophic failure (P_{cat})**: this score is linked to the DIS computed in Step #A. The relationship between DIS and the probability of a catastrophic failure is given by the formula used in RAT as follows [RD1]:

$$P_{cat} = 0.1e^{-0.069 \cdot DIS} \qquad (1)$$

This formula and the following ones are the results of desk analysis of available data and information, complemented by expert judgment. The formula was obtained by interpolating two extremes' values (DIS = 0 corresponding to 10^{-1} of P_{cat} and DIS = 100 corresponding to 10^{-4} of P_{cat}). The exponential parameter was determined by identifying intermediate values for two specific UAS models for which the target probability of catastrophic failure was known. Two independent experts computed the DIS and used these values to define two additional interpolation points.

b. **Probability for UAS to exit the operational volume (P_{exit}):** the relationship between CS and the probability for the UAS to exit the operational volume is as follows:

$$P_{exit} = P_{cat} \times 10^{-CS} \qquad (2)$$

The model assumes that if no containment is in place (i.e. CS = 0), the probability of exiting the operational volume is equal to the probability of catastrophic failure. This assumption derives from the consideration that any fly-away must be considered as a catastrophic failure since the pilot has no control on where the UAS is going to fly with an increased probability of crash and/or Mid-Air Collision. Details on how to compute the two scores are provided in Annexes C.1 and C.3.

2.3.3 Step #C: Operational scenario environment definition

This step is intended to determine the characteristics of the ground and airspace operational environment where the UAS considered in the previous steps can be operated safely. This step may or may not be carried out depending on the purpose of the verification process at NMAA level. If the NMAA is qualifying a system for use in a specific scenario, this step may not be needed as the scenario characteristics would have been already defined by the OPU. On the other hand, if the purpose is to define a "standard operating scenario" and qualify a system for this purpose, this step may be used to identify the scenario characteristics from the ground and air risk perspective. This step is thus further decomposed into two sub-steps dealing respectively with the ground and airspace characteristics.

The NMAA will define the characteristics of the scenario by referring only to the design and integrity of the UAS and the containment system assuming that the operator's and personnel competence as well as the mandatory equipment are adequate for the intended operation. Then the OPU will need in its own process to verify and validate these assumptions.

2.3.3.1 Step #C1: Operational ground area environment

In this sub-step, the maximum allowed **population density** that can be overflown is computed by considering the Area where the debris can be spread in case the UA would impact the ground, A_{impact} . If dangerous payloads are carried, the impact/crash area is computed taking into account the characteristics of the payload (see Annex A.4). The maximum allowable overflown population density expressed in people/km[2] is computed as follows:

$$PD = \frac{P_{Kill}}{A_{impact} P_{cat} (1 - E_r)(1 - S)} \quad (3)$$

Where:

- S is a Shelter factor to consider that some of the overflown people may be protected inside buildings. See annex A.3.1 for details on how to compute S. The default value is set to 0 unless it is possible to demonstrate that sheltering is present and effective.
- A_{impact} is the Area where the debris can be spread in case the UA would impact the ground.
- E_r is an Energy reduction factor to consider the availability of means to reduce the impact energy in case of a crash (e.g. a parachute). See annex A.3.2 for details on how to compute E_r. The default value is set to 0 unless it is possible to demonstrate that a system to reduce the impact energy is available and effective.
- P_{cat} is the probability of catastrophic failure computed using equation (1).
- P_{kill} is the maximum allowable probability of causing fatalities that have been set in Step #0.

Similarly, the maximum allowable population density of the adjacent areas expressed in people/km[2] is computed as follows:

$$PD_{Adj} = \frac{P_{Kill}}{A_{impact}(1 - E_r)(1 - S_{Adj}) P_{exit}} \quad (4)$$

Where P_{exit} is the probability of exiting the operational volume computed in Step #B and S_{Adj} is the shelter factor of the adjacent areas.

For further details on the Ground Risk model see ANNEX A .

2.3.3.2 Step #C2: Operational Airspace environment

In this sub-step, the type of airspace where it is possible to fly safely is determined depending on the characteristics of the UAS and its subsystems (i.e. the DIS). Each airspace is characterised by a maximum encounter rate[5] and an associated **Traffic Conflict Risk (TCR)** level. This is linked to the unmitigated probability to have a mid-air collision between a military UA and other manned traffic in each airspace (computation and evaluation of the encounter rate is contained in the Annex B.1.3.)

[5] Definition of the "Encounter rate" is provided in the Terms and Definitions table.

P_{cat} and the DIS computed in Step #B are associated with the maximum allowable encounter rate and its TCR (see Annex B.1.3) as follows:

P_{cat}	DIS	Max allowable encounter rate	TCR
[1E-2;1E-1]	[0;33]	1E-5/FH	1
[5E-4;1E-2]	]33;76]	3E-4/FH	2
< 5E-4	> 76	6E-4/FH	3
Not possible in MIL-UAS-SPECIFIC category		> 6E-4/FH	4

Table 1 - Relationship between Pcat, DIS, and airspace characteristics

According to the MUSRA Air Risk Model (see ANNEX B), it is not possible to demonstrate that operations in non-segregated airspace with an encounter rate higher than 6E-4/FH are safe using this methodology. This assumption is in line with the civilian regulation EU 2019/947 and related AMC that require the use of certified UAS to fly in higher risk airspaces (e.g. controlled airspace above 500ft AGL and below FL 600). This condition corresponds in SORA to a SAIL level of V or VI for which a certified UAS is required by EASA even if this does not prevent the operations to remain in the specific category in the civilian domain: i.e. neither formal pilot license nor mandatory certification of the organisation of the UAS operator.

Each of the above TCR levels are linked to a specific Operational Airspace Environment. Eight classes of Operational Airspace Environments have been identified considering different characteristics. These environments are linked to a **Traffic Encounter Category (TEC)** defining the likelihood of having an encounter with a manned aircraft.

The encounter rate of a given Operational Airspace Environment can be determined by carrying out airspace characterisation studies, using historical traffic data, and running simulations to determine the probability of having encounters. Airspace characterisation studies are costly and would require expertise in engineering, modelling, and simulation, as well as air traffic management and aviation systems safety. Therefore, a qualitative method for identifying initial collision risk is proposed to be used in those airspaces and situations where airspace characterisation studies cannot or have not been carried out for whatever reasons. As pointed out also in the SORA methodology that inspired this model, there are many factors that could affect a qualitative collision risk assessment. The proposed model tries to capture the most relevant factors using expert judgment, but local airspace conditions could vary. The Airspace Authority might therefore modify the Operational Airspace Environments categories and the related TCR levels.

The following table provides the association between P_{cat} , DIS, TCR level, TEC, and Operational airspace environment categories.

Categories	Operational airspace environment	TEC	TCR	P_{cat_air}
Controlled airspace	Around controlled Aerodromes	TEC 1	TCR 1	5E-5 Operations not possible in MIL-UAS-SPECIFIC category
	Controlled Airspace managed by Civil ATC (e.g. TMA, CTA, AWY, Routes, CTR)	TEC 2		
	Controlled Airspace managed by Military ATC (e.g. CTR)	TEC 3	TCR 3	5E-4

Uncontrolled airspace	Above sovereign territory/territorial waters including uncontrolled aerodromes	TEC 4		
	At or above 500ft AGL over international waters	TEC 5		
	Below 500ft AGL over international waters	TEC 6	TCR 2	1E-2
Reserved/Segregated airspace	Reserved areas with other involved operative traffic (e.g. DMA, transit corridors)	TEC 7		
	Reserved areas without any other involved operative traffic	TEC 8	TCR 1	1E-1

Table 2 - Relationship between Airspace Operational Environment TCR, Pcat, and DIS

On top of the overall design and integrity characteristics defined by P_{cat} and DIS, in order to operate in one of the above airspaces the UAS will need to fulfil a set of Minimum Detect and Avoid Requirements (MDAR) as presented in Table 3 and detailed in annex B.4

	Minimum Detect-And-Avoid Requirements (MDAR)	
	VLOS	BVLOS
Final TCR		
4	Operation not allowed in MIL-UAS-SPECIFIC category	
3	• Use of airspace observers (optional) • Availability of a de-confliction scheme • Communication phraseology and procedures	Detect-And-Avoid system with Medium Performance (RR = 0.33)
2		Detect-And-Avoid system with Low Performance (RR = 0.66)
1	No requirement	No requirement

Table 3: Minimum Detect and Avoid Requirements (MDAR)

Details on the full Air Risk Model are provided in ANNEX B .

2.3.3.3 Step #C3: Adjacent airspace considerations

In this step the characteristics of the adjacent airspace are determined based on the integrity of the containment system. The following table is used to identify which types of adjacent airspaces are allowed:

P_{exit}	TCR of adjacent airspace
[1E-2;1E-1]	1
[5E-4;1E-2]	2
]5E-4;1E-6]	3
<1E-6	4

Table 4: Relationship between P_{exit} and adjacent airspace

2.4 The OPU process

The MUSRA process from the perspective of the OPU considers the same steps described in the previous sections (applicable to the NMAA) but reverses the order to consider the need to start from the characteristics of the scenario and use this information to determine the suitability of the UAS that is selected for the flight.

2.4.1 Step #1: Scenario description

This step is intended to define the characteristics of the operational scenario in which the UA flight will take place. The OPU should identify the characteristics of the overflown area (population density, sheltering, etc.) and the volume of the concerned airspace. This step is further decomposed into two sub-steps dealing respectively with the ground and airspace characteristics.

2.4.1.1 Step #1a: Ground Area

In this sub-step the maximum allowed **probability of catastrophic failure for the ground area** is computed considering the following parameters:

- Maximum allowable probability of fatalities.
- Overflown population density
- The area where the debris can be spread if the UAS impacts the ground
- Shelter factor of the overflown area
- Availability of systems to reduce the impact energy
- Carriage of dangerous payloads.
- The simultaneous presence of other UAS in the operational volume.

The above list is taken from [RD2] and integrated with two new parameters to consider the availability of systems to reduce the impact energy (e.g. parachutes) and the carriage of dangerous payloads.

The maximum allowed probability of catastrophic failure is computed by considering the Area where the debris can be spread in case the UA would impact the ground, A_{impact} . If dangerous payloads are carried, the impact/crash area is computed taking into account the characteristics of the payload carried. The maximum allowed probability of catastrophic failure considering only the ground area characteristics is then obtained as (if no other UAS are expected in the area):

$$P_{cat\_ground} = \frac{P_{Kill}}{A_{impact} PD (1 - E_r)(1 - S)} \quad (5)$$

Where:

- S is a Shelter factor to consider that some of the overflown people may be protected inside buildings. See annex A.3.1 for details on how to compute S. The default value is set to 0 unless it is possible to demonstrate that sheltering is present and effective.
- E_r is an Energy reduction factor to consider the availability of means to reduce the impact energy in case of a crash (e.g. a parachute). See annex A.3.2 for details on how to compute E_r. The default value is set to 0 unless it is possible to demonstrate that a system to reduce the impact energy is available and effective.
- PD is the population density of the overflown area in people/km^2.
- P_{kill} is the maximum allowable probability of causing fatalities that are set in Step #0.

If more than one UAS is operated in the area at the same time, the probability of collision between UAS has to be considered as indicated in annex A.7.

Similarly, the maximum allowable probability of exiting the operational volume is computed as:

$$P_{exit\_ground} = \frac{P_{Kill}}{A_{impact}(1 - E_r)(1 - S_{Adj})PD_{Adj}} \qquad (6)$$

Where S_{Adj} is the shelter factor of the adjacent areas.
For further details on the Ground Risk model and how to compute the parameters of the above equations, see ANNEX A .

2.4.1.2 Step #1b: Airspace

In this step, the OPU identifies the **operational airspace environment** and the **adjacent airspace** in which the UA flight is intended to take place and the related TEC and TCR levels. Table 5 shows the association among the airspace categories, operational airspace environment, the TEC and TCR level.
From Table 5 the operational unit shall also identify the maximum allowable probability of catastrophic failure P_{cat_air} that is only related to the intrinsic characteristics of the airspace where the flight takes place (i.e. the operational volume) and the characteristics of the adjacent airspace.

Categories	Operational airspace environment	TEC	TCR	P_{cat_air}
Controlled airspace	Around controlled Aerodromes	TEC 1	TCR 4	5E-5 Operations not possible in MIL-UAS-SPECIFIC category
	Controlled Airspace managed by Civil ATC (e.g. TMA, CTA, AWY, Routes, CTR)	TEC 2		
	Controlled Airspace managed by Military ATC (e.g. CTR)	TEC 3	TCR 3	5E-4
Uncontrolled airspace	Above sovereign territory/territorial waters including uncontrolled aerodromes	TEC 4		
	At or above 500ft AGL over international waters	TEC 5		
	Below 500ft AGL over international waters	TEC 6	TCR 2	1E-2
Reserved/Segregated airspace	Reserved areas with other involved operative traffic (e.g. DMA, transit corridors)	TEC 7		
	Reserved areas without any other involved operative traffic	TEC 8	TCR 1	1E-1

Table 5: Relationship between Airspace Operational Environment TCR and P_{cat_air}

<u>Air Risk Mitigations (OPTIONAL)</u>

The OPU may then decide to implement **mitigations** to lower the TCR level, if deemed necessary and if adequate mitigations are available. This process is only applicable for the operational volume while the TCR level of adjacent airspace cannot be lowered.

To quantitatively evaluate the effectiveness of the applied mitigations, these are associated with a score named *ARMS (Air Risk Mitigations Score)*. To reduce the initial TCR level to a lower level (final TCR level) a minimum ARMS would be needed as presented in the table below:

FROM: Initial TCR level	TO: Final TCR level	Minimum ARMS
4	3	30
4	2	60
3	2	30

Table 6: ARMS - Air Risk Mitigations Score

It should be noted that it is not possible to lower the TCR to 1 using strategic mitigations. The only possibility to obtain TCR 1 is to fly in segregated/reserved airspace.

Mitigations are divided into two sub-categories:

- Strategic mitigations are those implemented before the flight takes place
- Tactical mitigations are those implemented during the flight

Both types of mitigations are intended to reduce the probability of encountering other traffic.

The table below summarises the ARMS that each mitigation can provide.

			ARMS
Air risk Mitigations	Strategic Mitigations	Time of exposure	18
		Day/time of the operation	18
		UAS transit routes/Corridor	30
		Flight plan	12
		Dangerous area	6
		Strategic U-space services	30
	Tactical Mitigations	Increased separations	15
		Coordination/Communications with ATS units	12

Table 7: Air Risk Mitigations

The *Achieved total ARMS* is the sum of the individual score of each applied mitigation:

$$Achieved\ total\ ARMS = \sum (Mitigation\ Score)_i$$

To effectively lower the TCR (when possible), the Achieved total ARMS should be numerically sufficient to reach the minimum value required as presented in Table 6 (e.g. starting from TCR 4, the *sum* of mitigations to be applied to reach the yellow block should be at least equal to a value of 60), otherwise, the final TCR would remain identical to the Initial TCR.

The score associated with each mitigation was determined using expert judgment. However, it is acknowledged that a better and more objective evaluation of the effectiveness in reducing the risk would make the whole assessment more robust. EDA pMS, based on the national context, can change the values associated with each mitigation based on respective airspace safety assessment studies. These are needed especially when the mitigation relies on the provision of external services (e.g. U-space) whose reliability needs to be carefully evaluated. To carry out airspace safety assessment, the reference methodology is MEDUSA, developed by EUROCONTROL in the framework of the CORUS project but other methodologies may be used as deemed appropriate.

Once the Initial TCR has been reduced to a lower level using Air Risk Mitigations, the Final TCR is used to determine the maximum allowable probability of catastrophic failure (P_{cat_air}) using Table 5. The whole process is depicted in the figure below.

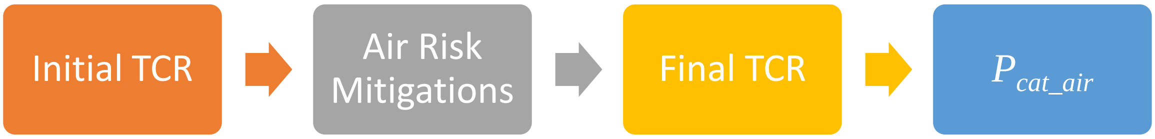

Figure 2: Step #3b: Air Risk Process

For further details and a description of each mitigation see Annex B.3. A questionnaire is provided and described in Annex C.4 to support the OPU in assessing the availability and effectiveness of Air Risk mitigations.

Minimum Detect-And-Avoid Requirements (MDAR)

Unless the Final TCR is 1, which means that the flight takes place in segregated airspace, MDAR are defined to mitigate the residual risk of having a MAC with other manned traffic. These requirements are associated with the performance of technical systems (e.g., Detect-And-Avoid System, Ground-Based Radar) or to an externally provided service (e.g. U-space de-confliction service). MDAR may vary depending on the final TCR level and the type of flight (i.e. VLOS or BVLOS). Table 8 presents a summary of the MDAR for each airspace TCR that are inspired by the SORA Tactical Mitigations Performance Requirements. Additional details are included in ANNEX B.4.

	Minimum Detect-And-Avoid Requirements (MDAR)	
	VLOS	**BVLOS**
Final TCR		
4	Operation not allowed in MIL-UAS-SPECIFIC category	
3	• Use of airspace observers (optional) • De-confliction scheme • Communication phraseology and procedures	Detect-And-Avoid system with Medium Performance
2	• De-confliction scheme	Detect-And-Avoid system with Low Performance

1	No requirement	No requirement

Table 8: Minimum Detect-And-Avoid Requirements (MDARs)

To verify that the MDAR are fulfilled, the OPU should fill in the **Minimum Detect-And-Avoid requirements Checklist (MDARC),** contained in Annex C.5.

If the MDAR cannot be fulfilled, the OPU should iterate the process going back to Step#1 to possibly modify the intended mission scenario. This could be done through:

- Reducing the Collision Risk of the Airspace in which the operation is intended to take place by use of Strategic mitigations or Temporary Segregated Areas (TSA).
- Changing the UAS or installing the required equipment to meet the MDAR.

Like the strategic mitigations, EDA pMS may modify the MDAR associated with each TCR level based on expert evaluation or analyses coming from airspace characterisation studies.

2.4.2 Step #2: Score computation

For the Operational Unit, this step is intended to determine the score related to the UAS design and the containment system required to safely fly the intended mission. Two scores are defined as follows:

a. ***Required Design and Integrity Score (RDIS)***: this score is computed by the OPU starting from the maximum allowable probability of catastrophic failure computed in Step #1. The lowest value between P_{cat_ground} and P_{cat_air} is taken as the reference value to make sure that the score is computed conservatively. The relationship between this score and the maximum probability of a catastrophic failure is given by the inverse of equation (1) as follows:

$$RDIS = -\frac{\ln(10P_{cat})}{0.069} \qquad (7)$$

Where $P_{cat} = min[P_{cat\_ground}; P_{cat\_air}]$

b. ***Required Containment Score (RCS):*** this score indicates the reliability of the containment system. The relationship between this score and the probability for the UA to exit the operational volume is as follows:

$$RCS = -\log\left(\frac{P_{exit}}{P_{cat}}\right) \qquad (8)$$

Where P_{exit} is the minimum value between P_{exit_ground} computed from equation (6) and P_{cat_air} of the adjacent airspace.

2.4.3 Step #3: UAS verification and score correction

In this step, the OPU would verify that the UAS selected for the mission fulfils the required scores computed in Step#2. This step is further decomposed into two sub-steps.

2.4.3.1 Step#3a: Verification of Design and Integrity Score

In this step, the OPU verifies that the Design and Integrity Score (DIS) of the UAS selected for the mission is sufficient (i.e. equal to or greater than the RDIS computed in Step #2). The DIS score associated with the selected UAS should be obtained from the NMAA, if the NMAA has completed the process described in section 2.3 after having received an application from another OPU or after having assessed the design of a new platform on their initiative. If this would not be the case, the OPU should request cooperate with the UAS manufacturer to gather the information to be submitted to the NMAA for the verification process.

The DIS score provided by the NMAA is based on the assumption that the OPU organisation and personnel competencies are suitable and that the planned mission would not exceed the limits established by the NMAA. To verify that this is the case, the OPU should complete an **Operational Questionnaire**. The results of this questionnaire are used to either confirm or reduce the initial DIS. The assumption is that the probability of a catastrophic failure depends not only on the Design Characteristics of the UAS but also on the capability of the organisation and of the personnel to properly manage the mission. The DIS is reduced based on the answers to the Operational Questionnaire provided in annex C.2 according to the following correction matrix.

	Organization	Adopted Design Standards	Tested Usage Spectrum	Stab Control / Nav Accuracy & Emergency Cond.	Ground Control Station	Structural Integrity	Propulsion Integrity	System Integrity	Safety Demonstration	Software Integrity	Continued / continuing Airworthiness
No evidence of operational procedures	1	1	0.5	0.5	0.5	0.5	0.5	0.5	1	1	1
No evidence of remote crew training	1	1	0.5	0.1	0.1	0.5	0.5	0.5	1	1	1
No evidence of external service SLA	1	1	0.5	0.5	1	1	1	1	1	1	1
No evidence of *maintenance* organisation and competences at operator's level	1	1	1	0.1	0.1	0.5	0.5	0.5	1	1	0.5
No evidence of Blast/impact	1	1	0.5	0.5	1	0.5	1	0.5	0.1	0.5	0.5
No evidence of mission-planning aspects	1	1	0.1	0.5	0.5	1	1	1	0.1	1	1

Figure 3: Operational correction matrix

Correction factors were defined using expert judgment and can be adapted by EDA pMS, including as a consequence of accruing experience and information from actual operations. The factors used are as follows:

- **0.1** means that the corresponding score obtained in the DIAC in Step#A is reduced by a factor of 10. This implies a significant impact on the related domain. For example, the absence of adequate remote crew training for the UAS selected for the mission may severely affect the capability of the crew to properly manage the UAS thus affecting the management of emergency conditions and navigation performance.
- **0.5** means that the corresponding score obtained in the DIAC in Step#A is reduced by half. This implies a major impact on the related domain. For example, the absence of adequate operational procedures may affect the capability of the crew to maintain the UAS within its Tested Usage Spectrum thus affecting the evaluation carried out by the NMAA.
- **1** means that the corresponding score obtained in the DIAC in Step#A is not affected and therefore it remains unchanged.

Final DIS, computed after having applied the correction factors in Figure 3, is then compared with the RDIS of the UAS to be used for the mission. If the final DIS is higher or equal to the RDIS of the UAS, the operation can be conducted. Otherwise, the OPU would need to iterate the process by implementing the required operational measures (e.g. additional training) or going back to Step#1 to modify the mission scenario by either:

- Changing the UAS selected for the mission (i.e. choosing one with a higher DIS); and/or

- Reducing the P_{cat_ground} by e.g. changing the flight trajectory to reduce the population density of the overflown area and/or varying the time of the day to increase the shelter factor, or by installing a parachute; and/or
- Reducing the P_{cat_air} by e.g. segregating the airspace or by applying additional air risk mitigations.

The whole process of Step #3a is presented in Figure 4.

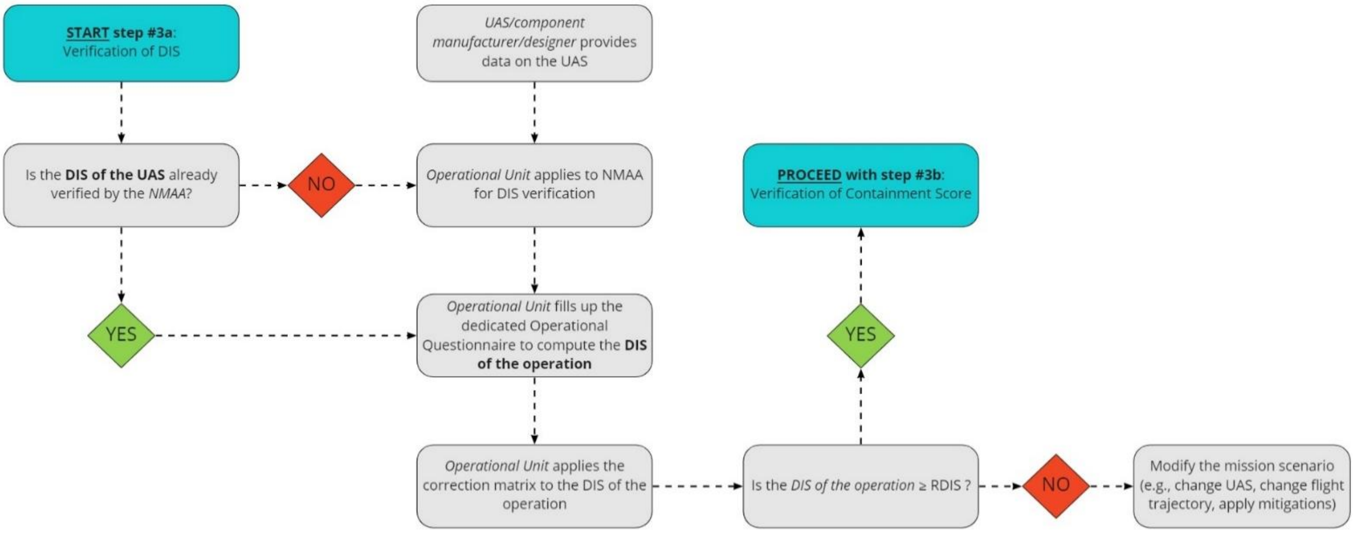

Figure 4: Step #3a Operational Unit

2.4.3.2 *Step #3b: Verification of Containment Score*

In this final step, the OPU would verify that the Containment Score (CS) of the UAS selected for the mission is adequate. Initial CS associated with the UAS selected should be obtained from the NMAA, if the NMAA has completed the process described in section 2.3.2 after having received an application from another OPU or after having assessed the design of a new platform on their initiative. If this would not be the case, the OPU should request the NMAA to initiate the verification process for the containment function.

RCS computed in Step#2 is compared with the CS of the UAS to be used for the mission:

- If the CS is higher or equal to the RCS, the operation can be conducted.
- Otherwise, the OPU would need to iterate the process going back to Step#1 to modify the mission scenario. This could be done by:
  - Changing the UAS selected for the mission (i.e. choosing one with a higher CS); and/or
  - Changing the flight path or the time of the day to reduce the population density of the adjacent areas that are exposed to the risk; and/or varying the time of the day to increase the shelter factor of the adjacent areas.

ANNEX A Ground Risk Model

A.1 Introduction

The Ground Risk model used by MUSRA methodology is based on the models proposed by RAT [RD1] and pRAT [RD2]. These two models are taken as the baseline and new elements are suggested. In particular, the MUSRA Ground Risk Models consider also:

- the characteristics of adjacent areas
- the carriage of dangerous payloads
- the availability of systems to reduce the impact energy

A.2 Initial Ground Risk

MUSRA Ground Risk Model aims to ensure that the risk of causing fatalities on the ground is not greater than P_{kill} that is set at national level (see 2.2) in the Step#0 of MUSRA. P_{kill} is therefore linked to the combination of the probability of having a catastrophic failure of the UAS leading to a crash and the probability of hitting someone on the ground, P_{hit}. If there are no systems to reduce the impact energy, the model assumes that a fatality will occur every time there is a catastrophic failure, **and** a person is hit. The relationship between the three terms is the following:

$$P_{Kill} = P_{Hit} \cdot P_{cat\_ground} \qquad (9)$$

From this equation, once P_{kill} is set, the maximum allowed probability of hitting a person on the ground can be determined as follows:

$$P_{Hit} = P_{Kill} / P_{cat\_ground} \qquad (10)$$

Where P_{Hit} can vary between 0 and 1.

The maximum allowed population density that can be overflown is then computed by considering the Area where the debris can be spread if the UAS impacts the ground. The probability of hitting people on the ground is a function of the wingspan, speed, maximum take-off weight of the UAS, and the overflown population density (PD) as follows:

$$P_{Hit} = A_{debris} \cdot 10^6 \cdot PD \qquad (11)$$

Where:

- P_{Hit} is the maximum allowable probability of hitting a person defined in (10);
- A_{debris} is the crash/impact area [m^2];
- PD is the population density [people/km^2].

The crash/impact area is calculated as:

$$A_{debris} = K \times b^2 \qquad (12)$$

Where:

- $K = min[50; E \times 0.0175 + 3.2858]$ and
- b is the UAS characteristics dimension (e.g. wingspan, rotor diameter) in [m].

This formula was derived by RAT authors by applying a model used for satellites impact validated using data from a number of real accidents.

The kinetic impact energy of the UAS is calculated as:

$$E = (0.5 \times m \times V^2)/10^3 \quad (13)$$

Where:

- E is the kinetic energy of the UA at impact [kJ],
- m is the UA MTOM [kg],
- V is the UA impact velocity [m/s].

The maximum allowable overflown population density is then obtained as:

$$PD = \frac{P_{Kill}}{A_{debris} P_{cat\_ground}} \quad (14)$$

A.3 Ground Risk Mitigations

A.3.1 Shelter factor estimation

If people on the ground are somehow protected from a possible impact, this can be taken into account by considering a Shelter Factor, S. The definition of the Shelter Factor follows the model proposed by pRAT [RD2]. The approach is reported hereafter for convenience.

The estimation of the Shelter factor depends on several elements that must be considered and that depend on two main factors [RD2] :

- Factor 1: The type of UA flying affects its capacity of penetrating a building/structure when crashing (*Protection_Factor*) and the lethality it causes when hitting a person (*Fatality_Factor*). Up to now, the model assumed that a fatality would occur every time a person is hit. The Shelter Factor is introduced to relax this assumption.
- Factor 2. The daily movements of the population within the areas that are overflown by the UA (*Mobility_rate*). The exposure to risk of the people on the ground (*Exposure*) to a crash of the UA will be different when they are sheltered (e.g. inside buildings) and unsheltered (outside or moving).

While Factor 1 depends on the UA, Factor 2 depends on the characteristics of the area of operations (e.g. urban, residential, rural, etc.) and on the daily mobility pattern of the inhabitants. Therefore, Factor 2 must be defined by each pMS depending on the geographical location.

Estimation of Factor 1

Factor 1 can be computed as follows:

$$Factor_1 = Protection_{factor} \cdot Fatality_{factor} \quad (15)$$

The Protection factor is given by the ability of a certain UA to penetrate a building when it hits its structure. The Protection factor is considered a minimum for the case of e.g. the Reaper, in which the estimated protection provided by the buildings avoiding their penetration is around 0,75 (25% of the times a UAs of this type crashes and hits a building, it penetrates its´ structure). For the case of UAs as the Scan Eagle, this estimated factor is 0,9 (only 10% of the times one UA crashes against a building, it will penetrate a building).

[RD6]. To allow for a quick determination of the Protection factor, the following formula can be used as proposed by [RD2] :

$$Protection_{factor} = -MTOW \cdot 3 \cdot 10^{-5} + 0.9008 \qquad (16)$$

The Fatality factor is the lethality factor of the hit which depends on the energy of the UA in the impact. Although this factor may depend on the carriage of dangerous goods the shelter model considers the lethality as dependent only on the mass of the UA. Fatality is considered the maximum for the case of the Reaper, which will cause death for all people hit by the UA and only 50% for UAs with geometry and performance like the Scan Eagle. To allow for a quick determination of the Fatality factor, the following formula can be used as proposed by [RD2]:

$$Fatality_{factor} = -MTOW \cdot 1 \cdot 10^{-4} + 0.5025 \qquad (17)$$

Combining equations (16) and (17) following (15) leads to the following expression for Factor 1:

$$Factor_1 = -MTOW \cdot 1 \cdot 10^{-4} + 0.4526 \qquad (18)$$

Where the quadratic term is neglected.

Estimation of Factor 2

Factor 2 can be computed as follows:

$$Factor_2 = Mobility_{rate} \cdot Exposure \qquad (19)$$

Factor 2 represents the percentage of the population that is protected inside buildings during the UAS flight. This factor is computed as the combination of the Mobility rate of the population which is the percentage of inhabitants that leave their houses during the day on a daily basis and the exposure rate which is related to the amount of time people spend outside when they are not at home. For example, from a study carried out in Portugal [RD39] the mobility rate is estimated to be on average 80%, which means that daily, 20% of the population remains sheltered in their houses. The exposure time is estimated to be 70 minutes during a working day. However, these 70 minutes are not evenly spread over the duration of the day with most of them being concentrated between 07:00 am and 01:00 am. By combining this data, Portugal estimated that the percentage of the population that is protected between 07:00 am and 01:00 am on a typical working day is around 95%. To properly take into account the sheltering in the Ground Risk Model, each pMS should define its percentage of the protected population depending on the geographical location and the time of the day.

Once the two factors are estimated, the Shelter factor is obtained as follows:

$$S = (Factor_1 \cdot Factor_2)/1.5 \qquad (20)$$ [6]

[6] The Safety Factor of 1,5 is introduced as a design Safety factor in order to account for the estimations of the model. This factor is introduced to reduce the effect of the Shelter factor, making the model more conservative.

A.3.2 Mitigation means to reduce the impact energy

UAS may be equipped with a system to reduce the lethality of an impact. Examples of these systems include but are not limited to: parachutes, autorotation, frangibility features.

According to [RD7], there is a 10% probability of causing fatal injuries with an impact energy of 49J. This probability is reduced to 1% with an impact energy of 32J. Assuming that 65% of the kinetic energy of the UAS is transferred at impact[7], a 90% reduction of the UAS lethality can be achieved by using a system that can reduce the kinetic energy of the UAS below around 80J. This is also the limit used in the EU Reg. 2019/947 [RD8] for UAS allowed to fly over people in the Open Category. On the other hand, the same study cited above has determined that the probability of causing fatal injuries increases to 90% with an impact energy of 143J. By taking these values as a reference, the impact energy reduction can therefore be computed as follows, assuming a quadratic relationship between the Energy reduction factor and the UAS Kinetic energy at impact.

$$E_r = -1.8 \cdot 10^{-5} \cdot E^2 - 3.31 \cdot 10^{-4} \cdot E + 1.0411 \qquad (21)$$

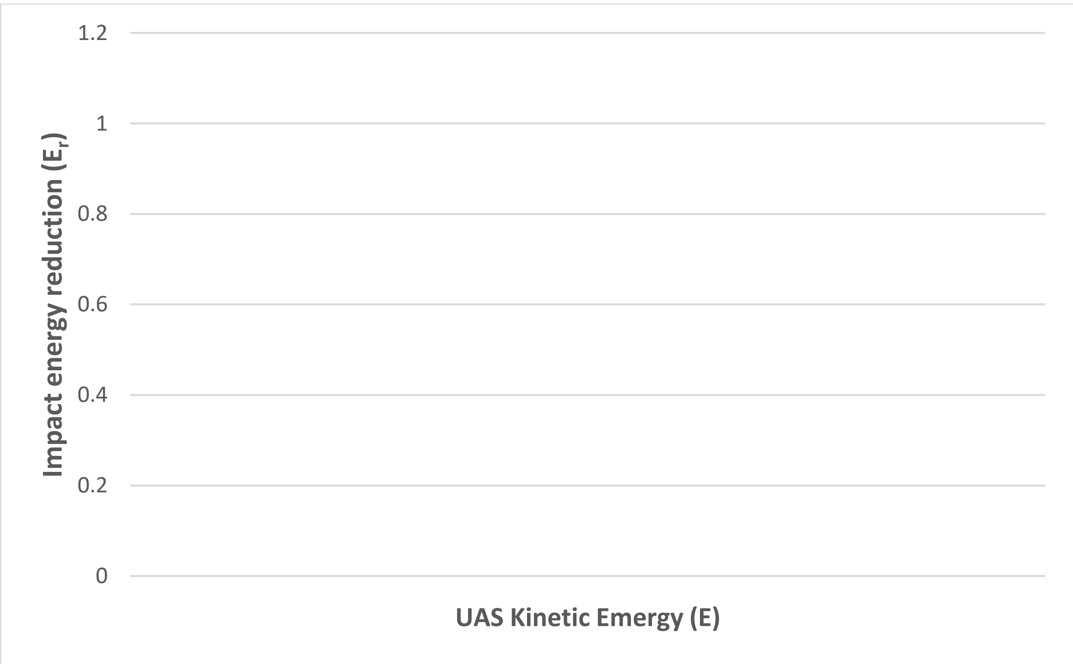

Figure 5: Quadratic relationship between the E_r and E at impact

A.4 Carriage of explosive payloads

Carriage of explosive payloads may affect the dimensions of the area where the debris is spread. The area within which the debris is spread is computed using equation (12) which is developed based on experimental data but without considering any explosive payload onboard. If explosives are carried and there is no

[7] EASA NPA 2017-05 (pag. 119) refers to 46.5% as the amount of energy transferred at impact and makes reference to a study from the Australian CAA and Monash University of 2013 entitled "Human injury model for small unmanned aircraft impacts". However since both EASA assumptions and the paper referenced refer to small UAS, a more conservative value of 65% is taken as reference.

mitigation to contain the explosion at impact, the area where the debris is spread can be computed based on [RD9] as follows:

$$A_{dangerous\_goods} = 1.263 \cdot 10^6 \cdot AUW^{1/3} \qquad (22)$$

Where:

- $A_{dangerous\_goods}$ is the area where the debris is spread in [m^2].
- AUW is the All Up Weight which is the total weight of the munition, or munitions, including packaging and palletization.

If explosives are carried the A_{impact} to be used to determine the maximum overflown population density is

$$A_{impact} = max\left[A_{debris}; A_{dangerous\_goods}\right]$$

A.5 Final Ground Risk

Maximum population density that can be overflown is defined by equation (14) without considering any mitigating or worsening factor. If these are considered, the population density becomes:

$$PD = \frac{P_{Kill}}{A_{impact} P_{cat\_ground} (1 - E_r)(1 - S)} \qquad (23)$$

If the ground risk model is used to determine the maximum probability of catastrophic failure of the UAS to overfly a given population density, equation (23) can be reversed to obtain the maximum allowable probability of catastrophic failure:

$$P_{cat\_ground} = \frac{P_{Kill}}{A_{impact} PD (1 - E_r)(1 - S)} \qquad (24)$$

A.6 Evaluation of adjacent area characteristics

The objective of this model is to address the risk posed by a loss of control of the UAS resulting in an infringement of the adjacent areas on the ground. Since these areas may vary with different flight phases the one with the highest population density should be considered to drive the identification of the containment requirements. The probability of causing fatal injuries in an adjacent area depends on the combination of the probability of exiting the operational volume and the probability of hitting a person once the fly-away has occurred, as follows:

$$P_{kill\_adj} = P_{Hit\_adj} \cdot P_{exit} \qquad (25)$$

P_{Hit_adj} is the probability of hitting a person in the adjacent area and it depends on the area within which the debris is spread in case of impact, the population density and the shelter factor of the adjacent area, as follows:

$$P_{Hit\_adj} = A_{impact} \cdot PD_{Adj} \cdot (1 - S_{adj}) \qquad (26)$$

The maximum allowable population density of the adjacent areas can therefore be derived from the above equations, also considering the availability of systems to reduce the impact energy, as follows:

$$PD_{Adj} = \frac{P_{Kill\_adj}}{A_{impact}(1 - E_r)(1 - S_{Adj}) P_{exit}} \qquad (27)$$

Where P_{exit} is the probability of exiting the operational volume and S_{Adj} is the shelter factor of the adjacent areas.

If the model is used to determine the maximum allowable probability of exiting the operational volume, equation (27) can be reversed to obtain:

$$P_{exit} = \frac{P_{Kill\_Adj}}{A_{impact}(1 - E_r)(1 - S_{Adj})PD_{adj}} \quad (28)$$

A.6.1 Determination of P_{exit}

P_{exit} is the probability of leaving the operational volume. It depends on the performance of the containment system, as follows:

$$P_{exit} = P_{cat\_ground} \times 10^{-CS} \quad (29)$$

Where:

- CS is the Containment score that measures the level of performance of the containments system. This score can be computed using the questionnaire provided in annex C.3.
- P_{cat_ground} is the probability of catastrophic failure of the UAS.

The model assumes that if no containment is in place (i.e. CS = 0), the probability of exiting the operational volume is equal to the probability of catastrophic failure. This assumption derives from the consideration that any fly-away must be considered as a catastrophic failure since the pilot has no control anymore on where the UAS is going to fly with an increased probability of crash and/or Mid-Air Collision.

A.7 Operations with multiple UAS

A collision between two UAS with no people on board will only cause fatalities if people on the ground would be hit by the falling debris created by the collision. For this reason, operating more than one UAS at the same time in the same airspace is considered a worsening factor only for the Ground Risk.

If we assume that a collision between two UASs will always cause the crash of the two aircraft, the probability of having a MAC between two UASs is equal to the probability of having a catastrophic failure, as follows:

$$P_{cat\_ground} = P_{MAC\_UAS} \quad (30)$$

This value of P_{cat_ground} needs to be compared with the one obtained from equation (24) if more UAS are operated at the same time in the same volume. The value obtained from (30) must be lower or equal, otherwise the risk for people on the ground will be higher than what is required by equation (24). If this is not the case , the probability of having a MAC between two UA has to be mitigated using the strategies proposed by the Air Risk Model. Guidelines on how to compute P_{MAC_UAS} and mitigate it using strategic and tactical mitigation strategies will be provided in the next deliverable (D3 – Guidelines).

ANNEX B Air Risk Model

B.1 Air Risk overview

B.1.1 Background

Air Risk model of MUSRA is inspired by the SORA Air Risk Model as it is described in Annexes C, D, and G [RD10]. The concepts introduced by the SORA Air Risk Model have been revised to adapt the model to the military specificities and reduce the overall complexity of the process.

It is acknowledged that a model inspired by SORA can better accommodate the operator's perspective (i.e. risk only for its ownship) while failing to assess the risk at a wider level (i.e. risks connected to the presence of several aircraft in a given airspace volume) considering the contribution of all actors in the airspace, including not only airspace users, but also Air Navigation Service Providers (ANSPs), U-space service providers, etc.

This element is considered by suggesting that military authorities carry out airspace characterisation studies and airspace safety assessments whenever this is possible and needed, considering the available resources. These analyses may lead to modifying the assumptions used in the MUSRA Air Risk Model, while the process would remain always applicable. The way airspace characterisation studies and airspace safety assessment contribute to the overall Air Risk assessment process will be highlighted in the following sections.

B.1.2 Terms and definitions

The following terms and definitions are used in the MUSRA Air Risk Model.

- **Mid-Air Collision (MAC)** is defined [RD11] as two aircraft physically contacting each other while in flight.
- **Near Mid-Air Collision (NMAC)** is defined [RD38] as a boundary condition, being the boundary defined as a cylindrical volume of airspace centered on the UA with a horizontal radius of 500 feet (152 meters) and vertical height of 200 feet (61 meters) or ±100 feet (30 meters).
- **Encounter (Enc)** is a boundary condition; the SORA definition [RD38] is used here where two different Encounter boundary conditions are identified, depending on the airspace:
    - For uncontrolled airspace, the boundary is defined as a cylindrical volume of 3000 feet (915 meters) horizontally and ±350 feet (107 meters) vertically of another aircraft.
    - For controlled airspace, the definition in RTCA DO-365 [RD12] section 2.2.4.3.2 applies, where τ^{*}_{mod} is 120 seconds, Distance Modification (DMOD), and Horizontal Modification (HMD*) are 4000 feet (1220 meters), and h* is ±1500 feet (457 meters) [RD13].
- **Providence** [RD14] is the point at which, in the collision sequence, all other modes of mitigation have failed, and neither the pilot, DAA system, or ANSP (Air Navigation Service Provider), can have any influence on whether the two aircraft would collide. Providence is a conditional probability of a MAC given that an NMAC has occurred (P(MAC|NMAC)) and it is conservatively assumed as 0.1 [RD15][RD16] for manned aircraft vs. manned/large UA sized aircraft, and 0.01 [RD17][RD18] for manned aircraft vs. small UA sized aircraft in line with the SORA Annex G definition [RD38].

B.1.3 Calculations of Encounter Rates (P_{Enc})

SORA Air Risk model uses the equation below to derive the encounter rate (P_{Enc}) that is related to the density of aircraft in a given airspace.

$$P_{Enc} = \frac{TLS}{P(MAC|NMAC)P(NMAC|Enc)} \quad (31)$$

Where:

- Enc, is an Encounter, as defined in annex B.1.2 for controlled and uncontrolled airspace.
- P_{Enc} is the probability of having an encounter expressed in the number of encounters per single Flight Hour (FH),
- $P(MAC|NMAC)$ is Providence, the unmitigated[8] conditional probability of a MAC given that an NMAC has occurred,
- $P(NMAC|Enc)$ is the unmitigated conditional probability of a NMAC given that an Encounter has occurred,
- TLS is expressed as the maximum allowable number of MAC per flight hour. MUSRA Air Risk model assumes that this TLS is equal to the maximum probability of causing fatalities (P_{kill}) that is defined in Step#0 of the process (2.2). This conservative assumption implies that any MAC will result in a catastrophic event with at least one fatality.

The above equation can be used to define the maximum allowable encounter rate of given airspace where it is possible to fly without any Air Risk mitigation in place while meeting the TLS.

B.1.4 Unmitigated P_{Enc} for uncontrolled airspace

For operations in uncontrolled airspace, the SORA Air Risk model assumes that encounters generally occur at low relative velocity, lower altitudes, and between smaller aircraft. In these conditions the following values are recommended by SORA to compute the encounter rate in uncontrolled airspace considering no mitigation in place:

a) **TLS:** the SORA uses the value recommended by the Second FAA SAA Workshop [RD14], which is the less stringent historical TLS collision risk for predominantly General Aviation aircraft and is set to 1E-7 MAC per FH. [RD20][RD21][RD22][RD23][RD24][RD25][RD26][RD27][RD14].
b) **P(NMAC|Enc) [RD28]**: the unmitigated conditional probability of an unmitigated NMAC given an encounter is 0.05.
c) **P(MAC|NMAC)** [RD29]: Providence is the unmitigated conditional probability of a MAC given an NMAC was 0.01, for shorter wingspan UA to shorter wingspan fixed-wing aircraft.

Using equation (**31**), the unmitigated P_{Enc} for uncontrolled airspace is estimated to be 2E-4 encounters per flight hour. This rate was determined in SORA using historical traffic data mainly from the US. If similar data are available for Europe or individual EDA pMS, they can be used to better define the unmitigated encounter

[8] Unmitigated means that both aircraft are proceeding through the encounter completely unaware of each other, and therefore no action will be taken by either aircraft to avoid the MAC, NMAC and/or to remain well clear.

rate in uncontrolled airspace. This task to refine the value of the encounter rate could be under the responsibility of the military or civil ANSP or other relevant State entities but should not be a concern of the military OPU.

B.1.5 Unmitigated P_{Enc} for controlled airspace

For controlled airspace where encounters are generally at higher relative velocity, higher altitudes, and involving bigger aircraft, the following values are recommended by SORA to compute the unmitigated encounter rate:

a) **TLS:** the SORA uses the value recommended by the Second FAA SAA Workshop [RD14], which is the most stringent TLS collision risk for predominantly commercial aircraft, set to 1E-9 MAC per FH [RD30][RD31][RD32].
b) **P(NMAC|Enc):** the unmitigated conditional probability of an unmitigated NMAC given an encounter is 4.4E-4 [RD13].
c) **P(MAC|NMAC)**: providence is the unmitigated conditional probability of a MAC given an NMAC is 0.1, for longer wingspan UA to longer wingspan fixed-wing aircraft.

Using the equation above, the unmitigated encounter rate in controlled airspace is estimated to be 2.2E-5 encounters per flight hour.

B.1.6 Generalised P_{Enc}

Unmitigated P_{Enc} calculated above for uncontrolled and controlled airspace allows to define the maximum allowable encounter rate to meet the TLS without any mitigation in place. The MUSRA Air Risk Model assumes that an encounter rate of 2E-4 or 2.2E-5 for respectively uncontrolled and controlled airspace can only be achieved in segregated airspace, in which in fact UA flights could be allowed without any additional mitigation on top of the segregation itself that is used to keep the encounter rate below the required threshold. Based on this consideration, the model defines four levels of risk, named "Traffic Conflict Risk" which correspond to a given unmitigated encounter rate as follows:

TCR Level	Example of the type of airspace	Unmitigated encounter rate
1	Segregated or reserved	< 1E-5
2	Uncontrolled airspace below 500ft AGL over international waters	< 3E-4
3	Uncontrolled airspace at or above 500ft	< 6E-4
4	Controlled airspace managed by civil ATC	> 2E-4

Table 9: P_{Enc} examples

The value of 1E-5 for TCR 1 is used since segregation is expected to guarantee a lower encounter rate than the one computed in annex B.1.4 and B.1.5. The values for TCR 2 to 4 are extrapolated from the one used for TCR 1 using expert judgment. More accurate values can be used if airspace characterisation studies are available. Moreover, EDA pMS may decide to lower the TLS that is used to set the unmitigated encounter rate and modify accordingly the encounter rates for the non-segregated airspace categories.

The above model addresses only the risk of collision between UAS and manned aircraft. A collision between two UASs with no people on board will only cause fatalities if people are hit on the ground after the collision has occurred. For this reason, the unmitigated encounter rates are referred only to manned aircraft.

To achieve the TLS that is set at the national level in non-segregated airspace mitigations are required. Two possibilities exist:

1. Reduce the encounter rate: a reduction of the encounter rate in given airspace can be achieved by using strategic mitigations that are implemented before the actual flight takes place and tactical mitigations that are implemented during the flight. The former can take the form of flight plan submission and approval, establishment of flight corridors, etc. while the latter can be real-time coordination with ATC or monitoring aeronautical communications.
2. Reduce P(NMAC|Enc). Once the encounter rate in given airspace is set, to meet the TLS a Detect-And-Avoid capability must be available. This capability should provide a level of performance that is proportionate to the unmitigated encounter rate of the airspace where the flight takes place.

B.1.7 Detect-And-Avoid (DAA) performance requirements

DAA performance requirements are derived starting from equation (31), considering the Encounter rates defined in Table 9, as follows:

$$P_{mitigated}(NMAC|Enc) = \frac{TLS}{P(MAC|NMAC)P_{Enc}} \qquad (32)$$

The performance of the DAA is then defined in terms of Risk Ratio (RR) as the probability of an NMAC given an encounter has occurred, but <u>with</u> DAA function available, over the probability of NMAC given an encounter <u>without</u> DAA. The lower the RR, the better the Detect-And-Avoid is at preventing an NMAC.

$$Risk\ Ratio\ (RR) = \frac{P_{mitigated}(NMAC|Enc)}{P_{unmitigated}(NMAC|Enc)} = \qquad (33)$$

$$= \frac{TLS}{P(MAC|NMAC)P_{unmitigated}(NMAC|Enc)P_{Enc}} \qquad (34)$$

If TLS is set at 1E-7 for TCR 2 and TCR 3 and 1E-9 for TCR 4 and $P_{unmitigated}(NMAC|Enc)$ assumes the values defined in annex B.1.4 and B.1.5 depending on the characteristics of the airspace, using the formula above the following performance requirements are derived. For TCR 1 DAA is not required since, according to the model, the TLS can be met without any mitigation in place.

TCR Level	Example of the type of airspace	Unmitigated encounter rate	Detect-And-Avoid RR
1	Segregated	<= 1E-5	Not required
2	Uncontrolled airspace below 500ft AGL over international waters	<= 3E-4	0.66
3	Uncontrolled airspace at or above 500ft	<= 6E-4	0.33
4	Controlled airspace managed by civil ATC	> 6E-4	> 0.33

Table 10: Relationship between the type of airspace and DAA RR

The DAA levels of performance are determined based on several assumptions related to the encounter rates and unmitigated probabilities of having collisions in a given airspace as described in Annex B.1.3. EDA pMS may revise the above numbers based on more accurate analyses and airspace characterisation studies.

B.2 Airspace categories

To facilitate the implementation of the model described in annex B.1 a qualitative approach is proposed. To this end, the encounter rates are associated with different categories of airspace based on their respective traffic "density". Three categories of airspace are defined, as follows:

- **Controlled airspace**[9] - An airspace of defined dimensions within which air traffic control service is provided by the airspace classification. It includes a controlled aerodrome environment: a volume of airspace, defined by the Airspace Authority and/or ANSP, surrounding an aerodrome, laterally and vertically defined, within which arriving and departing manned aircraft typically fly.
- **Uncontrolled airspace**[10] – Airspace or aerodrome which is not a "controlled airspace/aerodrome".
- **Reserved/Segregated airspace** - Airspace of defined dimensions, above the land areas or territorial waters of a State, within which the flight of aircraft is restricted by certain specified conditions [RD35] / Airspace of specified dimensions allocated for exclusive use to a specific airspace user [RD36].

B.2.1 Airspace characterisation

Within the abovementioned airspace categories, eight different UAS operational environments have been identified. The eight *operational environments* are defined as follows:

1. Around controlled Aerodromes;
2. Controlled Airspace managed by Civil ATC (e.g. TMA, CTA, AWY, Routes, CTR);
3. Controlled Airspace managed by Military ATC (e.g. CTR);
4. Above sovereign territory/territorial waters including uncontrolled aerodrome;
5. At or above 500ft AGL over international waters;
6. below 500ft AGL over international waters;
7. In reserved areas with other involved operative traffic (e.g. DMA, transit corridors);
8. In reserved areas without any other involved operative traffic.

Each operational environment is associated with a *Traffic Encounter Category* (TEC) that is qualitatively related to the unmitigated probability of having an encounter in that airspace and the related *Traffic Conflict Risk level* (TCR level) that is related to the unmitigated probability of having a MAC in that airspace. The relationship between the Airspace categories, the TEC, and the TCR is presented in Table 11. It was defined using expert judgment and by taking inspiration from the SORA Air Risk model. However, it is acknowledged that local conditions may be different thus requiring a different association between operational environment TEC and TCR. EDA pMS can therefore modify the proposed table based on the assessment of local airspace conditions.

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[9] Controlled airspace is a generic term which covers ATS airspace Classes A, B, C, D and E [RD34], [RD35];[RD34][RD35];
[10] The term is implicitly defined in ICAO Annex 11 [RD34] and SERA [RD35] as all airspace which is not Controlled Airspace. The term covers ATS airspace Classes F and G;

Categories	Operational environment	TEC	TCR
Controlled airspace	Around controlled aerodromes	TEC 1	TCR 4
	Controlled Airspace managed by Civil ATC (e.g. TMA, CTA, AWY, Routes, CTR, …)	TEC 2	
	Controlled Airspace managed by Military ATC (e.g. CTR, …)	TEC 3	TCR 3
Uncontrolled airspace	Above sovereign territory/territorial waters including uncontrolled aerodrome	TEC 4	
	At or above 500ft AGL over international waters	TEC 5	
	Below 500ft AGL over international waters	TEC 6	TCR 2
Reserved/Segregated airspace	Reserved areas with other involved operative traffic (e.g. DMA, transit corridors, …)	TEC 7	
	Reserved areas without any other involved operative traffic	TEC 8	TCR 1

Table 11: Airspace categories, TEC and TCR

Within the "**controlled airspace**" category, three operational environments are included:

- "airspace «*around*» controlled aerodromes" which is defined in terms of vertical and lateral limits and considering the specific characteristics of the aerodrome such as traffic density, type of traffic, available procedures, etc. The controlled aerodromes are considered the type of airspace with the highest probability of encountering other manned aircraft. EDA pMS could define the volume of airspace to be considered as a controlled aerodrome environment depending on local considerations and taking into account that military aerodromes may deserve specific considerations to account for their specificities.
- "Controlled Airspace managed by «*civil*» ATC" which is associated with a higher TCR than the «*military*» one. The assumption behind this choice is that in civil airspace there is usually a higher traffic density than in the corresponding military one.
- "Controlled Airspace managed by «*military*» ATC (e.g. CTR)". In military airspace effective coordination procedures are expected to be established to reduce the probability of encountering other manned aircraft.

The "**uncontrolled airspace**" includes 3 operational environments:

- *"Above sovereign territory/territorial waters including uncontrolled aerodromes" located in airspace classified as F or G*. In this environment VFR manned traffic, both civil and military is expected to mainly fly in Visual Meteorological Conditions (VMC), but a limited number of IFR flight may be expected as well. EDA PMs could define the volume of airspace to be considered as an uncontrolled aerodrome environment. Military aerodromes may deserve specific considerations to account for their specificities.
- "*At or above 500ft AGL over international waters*" where military UAS operations could fly considering the capability to grant the «due regard». In both cases, TCR is set to 3 by comparing these

environments to the equivalent one proposed by SORA that is classified with a risk that is one level lower than the highest value.

- "*Below 500ft AGL over international waters*". In this environment military UAS operations could fly considering the capability to grant the «due regard». General air traffic (GAT) is not expected to be found below 500ftAGL above high seas except for emergency missions (e.g. search and rescue). No IFR (Instrument Flight Rules) flights are expected as well. The probability of encountering other traffic is estimated to be less than in the previous cases and therefore the TCR level is set to 2.

The "**Reserved/Segregated airspace**" includes two operational environments.

- The first option is the "*Reserved areas with other involved operational traffic (e.g. DMA, transit corridors)*". In this context, military UAS operations shall be planned through the Air Tasking Order (ATO) and all involved airspace is reported in the Airspace Control Plan (ACP). The UAS and the other military traffic may be "spaced", at a strategic level, via specific allocation of sections of the volume of airspace in the same operational areas. The UAS and the other military traffic might be even spaced by Airspace Control Authority (ACA) during live operations. Civil traffic would not be allowed to operate in the area. In the end, the probability of encountering other traffic is considered low and the TCR level is set to 2.
- The last option is the *"Reserved areas without any other involved operational traffic*". This is the condition with the lowest probability of encountering other traffic. Therefore, the TCR level is set to 1. In this case, military UAS operations would be conducted within reserved volumes of airspace, usually implemented as TRA (Temporary Reserved Area) or TSA (Temporary Segregated Area), included in the national AIP (Aeronautical Information Publication) and activated by NOTAMs. Therefore, the air risk would be intrinsically mitigated when the reserved area is implemented and activated.

B.2.2 Maximum allowable probability of catastrophic failure

The operational environments defined in the previous section are linked to the maximum allowable probability of catastrophic failure, P_{cat_air} ,that could lead to an uncontrolled flight This association was done using expert judgment and based on the association made in SORA between SAIL (Specific Assurance and Integrity Level) and Air Risk Classes.

TCR Level	Example of type of airspace	Unmitigated encounter rate	P_{cat_air}
1	Segregated	<= 1E-5	1E-1
2	Uncontrolled airspace below 500ft AGL over international waters	<= 3E-4	1E-2
3	Uncontrolled airspace at or above 500ft	<= 6E-4	5E-4
4	Controlled airspace managed by civil ATC	> 6E-4	< 5E-5 Operations not possible in MIL-UAS-SPECIFIC category

Table 12: Relationship between the type of airspace and P_{cat_air}

B.3 Air Risk mitigations

In the MUSRA Air risk process, two types of air risk mitigation can be applied to reduce the air risk if deemed necessary: Strategic mitigations and Tactical mitigations.

B.3.1 Strategic Mitigations

Strategic mitigations are mainly applicable in the mission planning phase or in any case before the UA takes off. The following **Strategic mitigations** are proposed:

1. Time of exposure – if the time in which the UAS flies in each airspace is limited, the probability of encountering other traffic is also reduced and therefore the actual TCR level of the airspace may be lowered;
2. Day/time of the operation – the density of traffic in given airspace may vary depending on the time of the day/month/year. For example, aerodromes and some airspace structures (e.g. CTR) may experience less traffic during the weekend, summer, or at sunrise or at the night. If the UAS flight is planned at a time when the traffic density would be reduced this may lead to a reduction of the TCR level;
3. UAS transit routes/corridors – pre-defined routes and corridors officially implemented in given airspace and known by other traffic can be used to reduce the probability of encountering other traffic. For example, let us consider a UA that is planned to fly along a transit corridor connecting the aerodrome of departure to the CTR border and vice versa. Other traffic is aware of the UA transit corridor via aeronautical maps and AIP and will therefore avoid crossing it, thus reducing the traffic density within the corridor;
4. Flight plan – If the obligation to file a flight plan would exist for uncontrolled airspace, this may increase the capability to coordinate with other traffic. In this way, other traffic may get information on time, route, altitude, and any other useful information, through ATS; Information reported in the Flight plan might improve the situational awareness of the pilots and ATS units. In addition, based on the flight plans, ATC might change the operational parameters (i.e. Flight level, route, operational time, etc.) reducing the probability of encountering other traffic.
5. Dangerous area - a NOTAM (Notice To Airmen) may be issued to disseminate information about UAS operation in a specific volume of airspace. The other traffic should be informed of UAS activity before take-off. The involved area is not restricted and is usable by other traffic: pilots can freely decide to cross or not the dangerous area. If the dangerous area is set this is expected to lead to a lower traffic density due to the foreseen dangerous activities reducing the probability of encountering other traffic.
6. Strategical U-space services - some U-space services might be applied if available. The effectiveness of this mitigation depends on the U-space service provided (e.g. tactical geofencing). Implementation of U-space is expected in the EU starting in January 2023 [RD37] and the implementation of the services should reduce the probability of encountering other traffic in U-space airspaces.

Each of the above strategic mitigation is associated with an *"Air Risk Mitigation Score"* (ARMS).

Strategic Mitigations ARMS					
Time of exposure	Day/time of the operation	UAS transit routes/ corridor	Flight plan	Dangerous area	Strategic U-space services

18	18	30	12	6	30

Table 13: Strategic mitigation scores

The value associated with each strategic mitigation has been assigned based on expert judgment. EDA pMS may change the proposed values as deemed appropriate considering the specificities of each national airspace.

B.3.2 Tactical Mitigations

The objective of the 'tactical mitigations' is still to reduce the probability of encountering other traffic but these mitigations are implemented during the execution of the mission. The following tactical mitigations are proposed:

1. Increased separations - ATC units might apply "enlarged" separations between manned and UAS traffic (double or more separation) in some volume of airspace (e.g. military CTR, civil CTR with very low traffic, around military aerodromes). In this case, specific procedures should be adopted and implemented. Therefore, due to the increased separation, the probability of encountering other traffic is reduced.
2. Coordination/Communications with ATS units - ATS unit supports the UAS operation by providing information about other traffic. Similarly, the other traffic is warned about the presence of the UAS in the airspace volume and this leads to a reduction of the likelihood of having encounters.

Each tactical mitigation, similarly to the strategic mitigations, is then associated with an ARMS.

Tactical Mitigations ARMS	
Increased separations	Coordination/Communications with ATS units
15	12

Table 14: Tactical mitigations scores

The value associated to each strategic mitigation has been assigned based on expert judgement. EDA pMS may change the proposed values as deemed appropriate considering the specificities of each national airspace.

B.3.3 ARMS values assignment for Air Risk Mitigations

The ARMS were defined using experts' judgment considering their contribution in reducing the probability of having an encounter in each airspace. ARMS values are multiples of 3, to maintain a proportion in the assignment and can vary from a minimum of 3, corresponding to a reduction in the probability of encountering other traffic of 3E-5/FH to a maximum of 30 which corresponds to 3E-4/FH.

ARMS are linked to quantitative reductions in the encounter rates. If airspace characterisation studies are available this may allow to quantitatively evaluate the benefit of the air risk mitigations. However, it is acknowledged that this may not be possible in most cases. Therefore a qualitative evaluation of the Air Risk mitigations is proposed in the table below.

AIR RISK MITIGATION	MAX VALUE	RATIONALE

Time of exposure	18	The benefit provided by this mitigation is proportional to the actual time of exposure and the specific area of the airspace where the flight takes place. For example, if the crossing of airspace with TCR 1 lasts 1 hour there is no reduction. If the crossing lasts an amount of time that is in the order of a few minutes and takes place in an area of the airspace that is not particularly congested (i.e. close to SIDs and STARs) then the benefit is estimated to be up to 18 points. Compared to other mitigations such as the separations procedures and/or UAS route/transit corridor it is considered less effective since there is no coordination with the other traffic.
Day/time of the operation	18	Flying at a specific time of the day can have a positive impact on reducing the encounter probability. For example, flying at night in uncontrolled airspace where VFR traffic flying in VMC is usually expected can provide a significant benefit. The actual score will depend on the type of traffic usually found in given airspace and how the time of operation may affect the probability of encountering such traffic. This mitigation is considered potentially more effective than other less quantifiable mitigations (dangerous area (NOTAM), flight plan,) as it may have an immediate impact on the risk reduction. Compared to other mitigations such as the separations procedures and/or UAS route/transit corridor it is considered less effective since there is no coordination with the other traffic.
UAS transit routes/Corridor	30	This is considered the mitigations with the highest potential benefit since it allows to physically separate the traffic. Depending on the level of service that is provided in the airspace and thus on the information that is distributed to the other airspace users about the corridor activation, the score can be up to 30.
Flight plan	9	This mitigation can only be used in uncontrolled airspace where the obligation to file a flight plan is usually not applicable. Instead, if such plan is filed, this is expected to increase the situational awareness of the ATM which can provide information about the presence of the UAS to other traffic. This may lead to a reduction of the encounter rate depending on the type of traffic in the airspace and their level of interaction with ATM services (e.g. AFIS).
Dangerous area	6	If a danger area is implemented within a given airspace, ATC may provide information to the users in the airspace surrounding the D area about military UAS activity. The low maximum score is due to the fact that other airspace users can always decide to fly across the dangerous area.
Strategic U-space services	30	The potential benefit to reduce the encounter probability of U-space services is high. However, it is still unclear how these services will be implemented, and further studies are needed to better evaluate their contribution to risk reduction. In MUSRA this element is

		considered for completeness, but it is acknowledged that airspace safety assessments will be needed to define the maximum score and the actual one for each U-space airspace.
Increased separations	15	If separations are increased in controlled airspace compared to the usual one, this can have a positive impact on the reduction of the encounter rate. In uncontrolled airspace, the effectiveness of this mitigation is lower or negligible. Compared to other mitigations it is considered less effective than the establishment of transit corridors that are published in the AIP but more effective than establishing a dangerous area because it allows better control of the distance kept from other traffic.
Coordination/Communications with ATS units	12	Coordination with ATS units can effectively support reducing the probability of having encounters, especially in those airspaces where all users are in contact with ATS. It is considered more effective than the establishment of dangerous areas since it allows continuous coordination with other traffic.

B.3.4 TCR reduction

Once Air Risk mitigations have been identified they can be used to possibly reduce the Initial TCR to a lower level. The ARMS associated with both available strategic and tactical mitigations is summed up to determine the Total ARMS. Depending on its value the TCR is reduced as reported in the table below:

FROM: Initial TCR level	TO: Final TCR level	Minimum Total ARMS
4	3	30
4	2	60
3	2	30

Table 15: ARMS: Air Risk Mitigations Score

It must be noted that it is not possible to lower the TCR to 1 using strategic mitigations. The only possibility to obtain TCR 1 is to fly in segregated/reserved airspace.

B.4 Minimum Detect-And-Avoid Requirements (MDAR)

After applying mitigations, if the Final TCR is 2 or higher, this means that a residual risk of having a MAC with manned aircraft exists and that this risk is not adequately mitigated. If this is the case, depending on the Final TCR, Minimum Detect-And-Avoid requirements need to be fulfilled. These requirements are associated with the performance of a technical systems (e.g. Ground-Based Radar) or an externally provided service (e.g. U-space de-confliction service). MDAR vary depending on the final TCR level as reported in the table below.

	Minimum Detect-And-Avoid Requirements (MDAR)	
	VLOS	BVLOS
Final TCR		
4	Operation not allowed in MIL-UAS-SPECIFIC category	
3	• Use of airspace observers (optional)	Detect-And-Avoid system with Medium Performance (RR = 0.33)

2	• Availability of a de-confliction scheme • Communication phraseology and procedures	Detect-And-Avoid system with Low Performance (RR = 0.66)
1	No requirement	No requirement

<u>It has to be noted that the UAS operation can be carried out only if all MDAR, defined for the specific final TCR level, are fulfilled.</u>

Minimum Detect-And-Avoid Requirements (MDAR) for BVLOS flights are identified depending on the required level of performance based on the proposal made by JARUS in the new draft Annex G [RD38], as follows:

- MDAR "Medium Performance": It is required that the UAS is equipped with a DAA system capable of detecting 90% of all aircraft in the Detection Volume. This can be achieved by relying on one or more of the following:
  - Use of on and/or off UAS sensors (i.e. IR, Radar, etc)
  - Use ADS-B In aircraft trackers
  - Use of Mode-S transponders
  - Use of Ground-based radars

- MDAR "Low Performance": It is required that the pilot has awareness of most of the traffic operating in the area in which the flight takes place. This can be achieved by relying on one or more of the following:
  - Use of on and/or off UAS sensors (i.e. EO/IR, Radar, etc)
  - Use of (web-based) real-time aircraft tracking services
  - Use Low-Cost ADS-B In/UAT/FLARM/Pilot Aware aircraft trackers
  - Monitoring aeronautical radio communication (i.e. use of a scanner).
  - Defense radar capability - Involvement of military radar units to get and disseminate information to/from other traffic.

UTM/U-Space service may also be used to support the Detect-and-Avoid capability, but this possibility is not currently considered due to the unavailability of such services and the need to carry out additional studies to evaluate their performance level.

The type of sensor to be used should be selected considering the type of traffic that is expected to encounter in the airspace where the flight will take place. On top of the detection capability the MDAR for BVLOS will also include the following:

- MDAR "Medium Performance":
  - An assessment of the human/machine interface and of the tools and methods utilized for the timely detection and avoidance of traffic. The time required for the pilot to act should be demonstrated to be less than 5 seconds [RD38].
  - The Maximum Command-to-Execute latency should be no more than 3 seconds, and the Normal Command-to-Execute latency is no more than 1 second [RD12].
  - The UAS should have the following minimum maneuver performance [RD13]:
    - Minimum achievable airspeed: 50 Knots

        - Rate of climb/descend: ≥ 500 ft/min
        - Turn rate: ≥ 3 degrees per second
    - The update rate and maximum latency of the system should be less than 3 seconds depending on the technology selected [RD12].
    - The failure probability of the system should be the same that is required for the whole system operated in a TCR 3 environment, i.e. < 5E-4/FH
- MDAR "Low Performance":
    - A de-confliction scheme is developed to explain the criteria used to decide if an avoidance maneuver is needed.
    - Maximum Command-to-Execute latency should be no more than 5 seconds, and Normal Command-to-Execute latency is no more than 2 seconds [RD12].
    - The UAS should have the following minimum maneuver performance [RD38]:
        - Rate of descent: ≥ 500 ft/min
    - The maximum latency for the intruder and own aircraft vector data should be less than 10 seconds with a minimum update rate of 5 sec [RD38].
    - The failure probability of the system should be the same that is required for the whole system operated in a TCR 2 environment, i.e. < 1E-2/FH

ANNEX C Score computation

C.1 Design and integrity score (DIS)

Calculation of the DIS of the UAS is a three steps approach:

1. Filling up the DIAC (Design and Integrity Assessment Checklist) to obtain an initial score based on the UAS characteristics: the initial score is the amount of the score obtained for each question.
2. Reducing or confirming the initial DIS (obtained in the previous step) using the correction matrix.
3. Applying penalisation factors if mandatory requirements are not fulfilled

C.1.1 Design and Integrity Assessment Checklist (DIAC)

Design and Integrity Assessment Checklist enables to evaluation of the design and the integrity of a specific UAS.

The DIAC covers the following aspects:

1. Organisation;
2. Design standards;
3. Tested usage spectrum;
4. Stability and control/navigational performance and emergency conditions;
5. Ground control station/control box
6. Structural integrity
7. Propulsion and feeding system integrity
8. System and equipment integrity
9. Safe demonstration
10. Software and Electronic Hardware integrity
11. Continuing and continued airworthiness

The person in charge to fill up the questionnaire ought to see it is compliant with the requirements and sub-requirements contained in the first column named "requirement". For some requirements, standards can be used as a reference as reported in red. Under the column "type of requirement," it is reported if is a

mandatory or desirable requirement: all the mandatory requirements shall be met. Each requirement and sub-requirement is associated with a maximum achievable score (column “Max. Score”) that can be assigned following the guidelines reported in the column “Partial score applicable to the method of compliance”.
Compliance with the requirement can be demonstrated through Document (Doc.), and/or verification and/or test.

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
1. ORGANISATION						
1.1 The UAS design and production organizations should deliver evidence of usage of approved processes for management of safety within the design and production of systems.	**Doc.**	**Chose only ONE of the 4 possible options**	The applicant is certified per ISO 9001 (generic quality system), for the design and production of the platforms **(1), AND** The applicant shows evidence of the procedures for the management of safety issues within the design and production of systems **(1)**	**2**		
			The applicant is certified per AS/EN ISO 9100 (specific for aerospace manufacturers), for the design and production of the platforms.**(3), AND** The applicant shows evidence of the procedures for the management of safety issues within the design and production of systems **(1)**	**4**		
			The applicant shows evidence of compliance to EMAR-21 (Subpart G or F) and J**;**	**5**		
			The applicant has no certification **(0), AND** The applicant shows evidence of the procedures for the management of safety issues within the design and production of systems **(1)**	**1**		
1.1.1 The applicant shall deliver evidence of the Quality System implemented.	**Doc.**	*Evidence may take the form of appropriate certifications and/or approvals (e.g. ISO 9001 or EN/AS 9100)*	Evidence available that work is undertaken by competent individuals (trained and qualified) **(1), AND** Evidence available that facilities, tools, material, procedures and data are adequate **(0.8), AND** Safety culture is demonstrated **(0.2)**: - The documented statement of the quality policy shall include explicitly system safety as one of the main objectives; - Safety management processes are implemented	**2**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
1.2 The applicant shall demonstrate that the materials and manufacturing processes used in the construction of the UAS are adequate.	**Doc.**		The suitability and durability of materials used are established on the basis of experience or tests. **(0.3), AND** Materials conform to approved specifications; **(0.7), AND** Manufacturing processes conform to recognized standards; **(1)**	**2**		
1.3 The applicant shall demonstrate that the materials and manufacturing processes used in the construction of the UAS are adequate.	**Doc**	**Chose only ONE of the 5 possible options** *For structural part a special/detailed procedure is to be considered NDT or similar test;For systems/avionics, functional tests are to be considered;*	Critical parts/systems/components are inspected by special/detailed procedures after manufacture (or before installation) for all items; **(1)**	**1**		
			Critical parts/systems/components are inspected by special/detailed procedures after manufacture (or before installation) on a sampling basis; **(0.7)**	**0.7**		
			Critical parts/systems/components are inspected after manufacture (or before installation)for all items, but without any special/detailed procedures; **(0.2)**	**0.2**		
			Critical parts/systems/components are inspected after manufacture (or before installation) on a sampling basis, but without any special/detailed procedures; (**0.1)**	**0.1**		
			No inspection is made **(0)**	**0**		
1.4 The applicant must demonstrate the existence of a process to manage design changes and communicate these to the Operators.	**Doc**		A process exists to communicate to known operators the Mandatory design changes; **(0.25), AND** The control of the implementation of the mandatory design changes is traced by the manufacturer; (actual feedback) **(0.05), AND** The organisation has a way (e.g. database) to properly identify which platform was delivered with which version of the systems **(0.2)**	**0.5**		
1.5 The applicant shall ensure that the operator is educated about the criticality of configuration management processes for the UAS.	**Doc.**	**Chose only ONE of the 3 possible options**	A digital system for configuration management is implemented **(0.5)**	**0.5**		
			Configuration management procedures are included in relevant manuals and personnel is trained accordingly **(0.3)**	**0.3**		
			another type of configuration management system is available and used **(0.3)**	**0.3**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
2. DESIGN STANDARDS						
2.1 The applicant shall show evidence of the design criteria and standards used to design the UAS structure, engine, propeller, and UAS systems and equipment.	**Doc.**	*The following questions are meant to be answered for the aircraft's critical systems, powerplant, critical structures, flight control subsystems (autopilot, actuators).*	1. Does the organisation design UAS structure, engine, propeller, and UAS systems and equipment? (if yes) 1.1 Does the design consider standards for the design of UAS structure, engine, propeller, and UAS systems and equipment? (if yes) Y1.1.1 Are the standards recognized for aeronautics? Yes=**(0.5), AND** Y1.1.2 Are the standards considered adequate? Yes=**(0.5)** (if no) 1.2 Does the organization have adequate control over the norms and specifications of the UAS structure, engine, propeller, and UAS systems and equipment? (if yes) Y1.2.1 Are the norms and specifications recognized for aeronautics? Yes= **(0.5), AND** Y1.2.2 Are the norms and specifications considered adequate? Yes=**(0.5)** **AND** 1.3 Is the manufacturer of the UAS structure, engine, propeller, and UAS systems and equipment recognized for the manufacture of these items within the market? Yes=**(0.5), AND** 1.4 Are the engines, propeller, and UAS systems and equipment used in other platforms (from other manufacturers) with adequate reliability? Yes=**(0.5)**	**2**		
3. TESTED USAGE SPECTRUM						
3.1 The applicant shall deliver the design usage spectrum as well as the set of all the foreseen operational conditions of the UAS	**Doc**	*The following standards may be used to test specific aspects:* *ASTM F3298-19: Standard*	The following parameters are included in the usage spectrum: 1. Velocities **(0.5), AND** 2. Load Factors **(0.5), AND**	**3**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
		Specification for Design, Construction, and Verification for Lightweight Unmanned Aircraft Systems (UAS).	3. Weather (Wind, Rain, moist, ice) **(0.5), AND** 4. Altitude **(0.5), AND** 5. MTOM **(0.5), AND** 6. Performance (climb rates, max bank, sideslips) **(0.5)**			
3.2 The applicant shall show evidence of how the design spectrum was defined.	**Doc.**		The following activities have been conducted: 1. Lab Testing **(0.05), AND** 2. Ground Testing **(0.05), AND** 3. Flight Testing **(0.05)** **AND** Enough and adequate testing have been performed **[0 to 1.1]**	**1.25**		
3.3 The applicant shall show evidence of the in-service experience accumulated.	**Doc**	*The applicant considers the experience to be sufficient, w.r.t* *i. number of in-service units;* *ii. number of known operators;* *iii. number of Known flight hours;* *iv. other produced and in-service models (if present)*	The in-service experience or flight testing is representative of the actual platform and configuration because it is conducted with the same platform with same configuration **(1.0)**; **OR** (decrease the score depending on the differences in the used platform) - Different Powerplant **[-0.2]**; - Different mainframe **[-0.5]**; - Different autopilot **[-0.15]**; - Different Surface actuators **[-0.15]**;	**1**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
3.4 The applicant shall show evidence that flight experience and/or in-service experience has demonstrated that the design is free from unsafe features in the complete operational spectrum.	**Doc**	*Note: This shall be demonstrated (for a configuration similar to the proposed UAS) through a statement referring to the ratio of known occurrences per flight hour, the number of investigations conducted, the number of necessary redesigns, and the number of eventual unsafe conditions identified.*	No major system of the platform has been involved in unsafe/accident conditions or the applicant has not been informed or is not aware of past/recent accidents with the platform, regardless of configuration **(0.5)** *If no occurrence exists, the applicant must STATE that no occurrence has been reported by the operators in the total of known flight hours.*	**0.5**		
3.5 The applicant shall show evidence that all safety-critical equipment is functioning properly throughout the full tested operational envelope when integrated into the UAS system (including ground station, datalink equipment, air vehicle, etc.).	**Doc.**	*Note: This shall be made through:* *Functional tests of the safety-critical systems including ground station, datalink equipment, air vehicle, etc.) for the operational envelope;* *Safety analysis for the safety-critical functions;*	Is there a way of ensuring that the systems have been fully tested at their functional level before installation on the platform? Yes=**(0.4), AND** Is there a system to ensure that when the system identifies problems, these problems are researched and corrected? Yes=**(0.1)**	**0.5**		
3.6 The applicant shall show evidence of the existence of a system to track problem reports from development and qualification tests of the UAS.	**Doc.**	*Note: The evidence can be the Approved Organization Manual with Statement with identification of the section in the approved organization manual where the system is identified*	Is there a way to follow or track Open Problem Reports (OPR)? Yes=**(0.5)**	**0.5**		
3.7 The applicant shall show evidence of the state of all the problem reports, that have derived from the development and qualification of the UAS.	**Doc.**	*Note:* *The applicant shall state all the reported problems that have derived from the development and*		**0.25**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
		qualification of the UAS. *If there are open problems yet under investigation, the applicant must identify eventual limitations to the UAS operating Manual that derive from the ongoing investigation of those reports.*	Is there a system to identify the state of the open problem reports that are derived during and qualification phase? Yes=**(0.25)**			
4. STABILITY AND CONTROL/NAVIGATIONAL PERFORMANCE AND EMERGENCY CONDITIONS						
4.1 The applicant shall show evidence that the UA is stable and controllable in all sequences of flight and on-ground (as applicable), in all operational modes, throughout the full operational envelope.	**Doc.**	*Note: Including wind conditions as applicable, phases of take-off/launch, and landing/recovery in the worst environmental condition (including wind).*	The applicant shall show evidence of complete testing of the aircraft for the limits of the flight envelope and the aircraft was shown to be stable and controllable for all the extent of the flight envelope. The above evidence is extracted from : - analyses **(0.5), AND** - rig tests **(0.5), AND** - flight tests **(1), AND** The evidence include: - quantitative evidence of adequate gain/phase margins **(0.25), AND** - adequate flying qualities **(0.25), AND** - the phases of take-off/launch and landing/recovery; **(0.25), AND** The test of these phases includes the worst environmental condition considered in the usage spectrum **(0.25)**	**3**		
4.1.1 The applicant shall show evidence that operational procedures exist for the phases of take-off/launch and landing/recovery.	**Doc.**	*Note: Sufficient evidence of the assessment of the procedures w.r.t the levels of safety and mitigation of any safety issues that have been identified.* *The flight manual should include the cautions of each operational procedure*	Is there evidence that these procedures are implemented in the Operations manual or the Flight manual? Yes=**(0.5), AND** Is there evidence of analysis of procedures of operation at the level of safety **(0.5)**	**1**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
4.2 The applicant shall show evidence of the existing flight control protecting System functions for: - **Stall;** - **speed exceedance;** - **over load;** - **dangerous oscillations;** - **spinning.**	**Doc.**	*Note: This evidence must be delivered in the form of documentation*	Evidence of existing control protecting System functions for: - Stall; **(1), AND** - speed exceedance; **(0.5), AND** - over-load; **(0.5), AND** - dangerous oscillations; **(0.5), AND** - spinning; **(0.5), AND**	**3**		
4.2.1 The applicant shall show evidence of all UAS features which are meant to minimise the effects of the operator mistake. (in all operational modes including direct piloting and semi-automatic modes as applicable).	**Doc**	*Note: Score is based on how many protections (and their margin) are in place. The Design Organization should provide information about protection requirements and corresponding evidence.* *If requirements and evidence are not provided score is zero.*	Evidence of UAS features available: - including direct piloting; **(0.5), AND** - semi-automatic modes as applicable **(0.5), AND** - fully automatic mode **(0.5)**	**1.5**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
4.3 The UAS should be stable and controllable after failure of sensors and primary aerodynamic control surface actuation (even if only in a degraded mode).	**Doc**	*The following standards may be used:* *ASTM F3298 – 19 - Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS),*	The applicant shall provide documentation demonstrating that the UAS maintains some stability and controllability, after failure of sensors and primary aerodynamic control surface actuation: - Pitot tube/ IAS failsafe **[0.5], AND** - IMU Failsafe **[0.5], AND** - GPS Failsafe **[0.5], AND** - Fail-safe design for main flight controls surface actuation **[1.5], AND** **OR** alternatively by: Demonstration by test evidence of ability to control after failure: - Pitot tube/ IAS failsafe **[0.5], AND** - IMU Failsafe **[0.5], AND** - GPS Failsafe **[0.5], AND** - Primary aerodynamic control surface **[1.5]**	**3**		
4.4 The applicant should demonstrate a minimum level of navigation precision adequate for the mission profile, and the precision tolerances shall be provided in the flight manual of the UAS.	**Doc**	*The following standards may be used:* - *ASTM F3298 – 19 - Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS),*	- GPS PDOP values; **(0 to 1)** - Is the UAS capable of SBAS augmentation? **Yes =(0.1)** - Nav Solution: • Wind < half of cross-max limit: min req: 10x max dimension of AC. **(0.2)** • and wind > half of cross-max limit, min req: 15x max dimension of AC. **(0.2)**	**1.5**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
4.5 The UAS must include means to monitor and indicate the UAS health status (including Data Link) to the Designated UAS Operator throughout the mission profile.	**Verification & DOC**	*Note: If this function does not exist, the UAS will fail.*	Proof of the following must be included: - Is there a way of monitoring the UAS data link on the Operator GCS? Yes=**(0.5), AND** - Has the UAS monitoring link been tested through flight testing? Yes=**(0.75), AND** - Does the system indicate loss of link through visual or sound warning? Yes=**(0.375), AND** - Does the system indicate loss of link through RSSI (Received Signal Strength Indication), link of another indicator? Yes=**(0.375).**	**2**		
4.5.1 The datalink performance must be shown to be sufficiently robust for the type of operations, ranges, and environment of the UAS.	**Test**		Test description: The applicant shall demonstrate by flight test adequate datalink level throughout a mission comprising operation near other systems, maximum operation altitude, and maximum range. - If no datalink loss is verified during the test **(2), OR** - If less than 3 datalink loss are verified **(1)**	**2**		
4.6 The UAS shall maintain safe operation in case of datalink loss.	**Doc.& Test**		The applicant shall show evidence of procedure for loss of datalink in the Flight Manual. - Procedure established to cope with loss of datalink for short period and long period with adequate warning of remote crew; **(0.75), AND** - Procedure defined to recover mission profile, upon reset of datalink **(0.25), AND** - existence of return to home (RTH) procedure: **(0.5), AND** - existence of a safe landing procedure for loss of datalink **(0.5)** Additionally, the applicant shall demonstrate by flight test that a data link	**2**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
			loss will not initiate unsafe operation or flight of the UAS.			
5. GROUND CONTROL STATION/CONTROL BOX						
5.1 The UAS MUST include means to interact with the Operator (Human-machine Interaction), allowing for the management of the mission workload and safety.	**Doc.**	*The following standards may be used:* - *ASTM F3298 − 19 - Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems (UAS),*	The following information must be provided to the remote pilot, depending on the type of operation/distance to the RP: For UAS intended to be flown within VLOS: - Elapsed Flight time - remaining battery/fuel - audible buzzer for low battery/fuel - visual/ audible warning for low link / RSSI (**0.5** if all the above are satisfied; **0** otherwise) For UAS intended to be flown BVLOS: - Elapsed Flight time - remaining battery/fuel - visual/ audible warning for low battery/fuel - visual/ audible warning for low link / RSSI - GPS status (PDOP/HDOP + Satellites) - Link and RSSI indication - Altitude - attitude - airspeed - distance to the home point - navigation solution status - engine power or RPM - control surface deflection command (**0.5** if all the above are satisfied; **0** otherwise) WORKLOAD The applicant shall deliver a Human Factors evaluation of the HMI **(0-1 to be determined by evaluator x 0.5)** Compliance shall be demonstrated by the existence of these functions in the Flight Manual.	**1**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
5.1.1 The information provided by the UAS to the operator must be sufficient, clear, unambiguous and should be readable in the worst light conditions.	**Verification**		The applicant shall show an image or document describing the remote pilot interface with all items identified before duly highlighted. (Verification of quality of information: Clear, complete unambiguous **[0.3]**) **AND** The applicant shall show evidence of GCS modifications that will assure operator readability in worst light conditions (e.g., screen protection for outdoor tactical GCS or high contrast screens, lateral view angle) **(0.2)**	**0.5**		
5.1.2 The UAS must show an adequate warning for malfunctions, failures, or any unsafe condition.	**Doc.& Verification**		The applicant shall show an image or document describing the remote pilot interface with all items identified before duly highlighted. Compliance shall be demonstrated by the existence of these functions in the Flight Manual. **(0.5)**	**0.5**		
5.1.3 The UAS shall provide to the operator information about limit exceedances and unsafe conditions of the UAS.	**Doc.& Verification**		The applicant shall show an image or document describing the operator interface with all itemsidentified before duly highlighted. Compliance shall be demonstrated by the existence of these functions in the Flight Manual. **(1)**	**1**		
6. STRUCTURAL INTEGRITY						
6.1 The UAS shall have defined the maximum operating limits for all the conditions (flight, ground, launch, recovery, transportation, handling, etc)	**Doc.**		Limits are to be established in the Flight Manual. (Limits to be described in the manual: Load factor, Speeds, rate of climb, max RPM, altitude, turn radius, attitude limits) (**0 to 1** based on evaluator's experience)	**1**		
6.1.1 The applicant shall show evidence that the UAS withstands, without rupture, the maximum operational loads multiplied by an adequate factor of safety, at each critical combination of parameters.	**Doc.**		The applicant shall deliver the Structural demonstration. (**0 to 1** based on evaluators experience) **Notes:** Maximum score may be achieved when loads	**1**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance		Max total Score	SCORE	RATIONALE
6.1.2 The applicant shall show evidence that all the structurally relevant metallic, composite and polymeric parts of the UAS do not yield (metallic) nor fail / permanently deform at the maximum operational loads.	**Doc.**		The applicant shall deliver the Structural demonstration. (**0 to 1** based on evaluators experience)	are established based on recognized aerospace standards and quantitative evidence of positive margin of safety on primary structural elementsare shown by an adequate combination of analyses and tests.	**1**		
6.1.3 The applicant shall show evidence that the UA is free from any aero–servo-elastic instability and excessive vibration	**Doc.**		The applicant shows that the UA is free from flutter, control reversal, and divergence in all configurations. **(1)**		**1**		
6.2 Is there evidence that fatigue inspections are put into the maintenance program for metallic and/or BVID inspections for composite structures?	**Doc.**		The applicant shall deliver the maintenance program. The applicant shall identify all components with fatigue limits. **(0 to 0.2)**		**0.2**		
6.2.1 The UAS maintenance programme should include a pre-flight checklist considering composite parts inspection	**Doc.**		The applicant shall deliver the maintenance program including the required items **(0.3)**		**0.3**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
for identification of damages.						
6.2.2 The applicant shall deliver a maintenance program that is able to ensure the structural integrity of UAS integrity throughout its service life	**Doc.**		The applicant shall deliver the maintenance program, which is to be evaluated for suitability. Areas to be considered in the maintenance program: - Corrosion inspections - life limit components - engine - main structural components **(1.5)**	**1.5**		
7. PROPULSION AND FEEDING SYSTEM INTEGRITY						
7.1 The applicant shall demonstrate the reliability of the UAS propulsion system.	**Test**		Applicant shall deliver detailed report of: - Inspections / maintenance during test cycle **(0 to 1), AND** - Inspection after tear down of powerplant **(0 to 1), AND** - Classification **(0 to 1)**, with **0** = no report submitted	**3**		
7.1.1 The UAS shall demonstrate adequate engine reliability by operational experience.	**Doc.**		The applicant shall deliver a document stating the reliability of the engine, and the number of flight hours upon which that statement is based upon. A failure rate for the propulsion system should be delivered. **Score = 3/0.8 * [1+1/log(failure rate)]** NOTE: The probability of failure larger than 10-3 will have a penalty of over 50% of the total score of the current question	**3**		
7.2 The applicant shall demonstrate that the Engine Control System (including propeller pitch) performs the intended functions in all its control modes throughout the full operational envelope	**Test**		Have the following been assessed and passed during the test phase: - propeller pitch if applicable **(0.25), AND** - fuel admission control **(0.25), AND** - air admission system **(0.25), AND** - refrigeration system **(0.25), AND**	**1**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
7.3 For *electrical engine* applications, the applicant shall demonstrate that the battery provides the necessary voltage and current required by the engine and electrical equipment throughout the operational envelope.	**test**		The applicant shall: 1) Include in the Flight Manual, the minimum value of current and voltage required for engine and electro avionic systems functioning **(1), AND** 2) Demonstrate by a test that during a mission covering the complete mission profile the power voltage supply and the current remains above those values (plus atolerance for possible degradation of battery performances) **(1)**	**2**		
7.4 For *combustion engine* applications, the applicant shall demonstrate that the fuel system provides the necessary fuel flow at the necessary conditions required by the engine throughout the operational envelope.	**test**		The applicant shall demonstrate by test, that during the complete mission profile, the fuel system allows for the supply of fuel for all requirements, without failures. Is there proof, under the form of a test, that the fuel system can supply the necessary fuel to the engine at all operating conditions? Yes=**(0 to 1)** depending on the description of the conditions that were tested No=**(0)**	**1**		
7.4.1 For *combustion engine* applications, the UAS must include a filtering system adequate to avoid those foreign particles passing through the engine will not critically affect engine functioning.	**Doc.**		The applicant shall deliver a document demonstrating that a failsafe design is considered for the filtering system, namely through a by-pass in the filtering device. Does the system include a filter that retains particles harmful to the engine? Yes=**(0.5)** No=**(0)**	**0.5**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE

7.4.2 For *combustion engine* applications, the applicant shall demonstrate that the engine oil system will function properly in the complete UAS operational envelope.	**test**		The applicant shall demonstrate by test, that during the complete mission profile, the lubricating system works without failures, and that the engine temperature does not rise above allowable values.
			The applicant shall state if the UAS lubricating system should be protected by suitable filter(s) or strainer(s).
			
			The applicant shall show that lubricant used and the lubrication system is adequate for the powerplant installed.
			The tests performed show evidence that:
			- The temperature did not rise above the limits **(0.5), AND**
			- For the oil-fuel mixture: Was there evidence of wear during tear down? **(0.5** if **no wear), AND**
			- For independence lubricant system:
			    o Was there a reduction of oil level below 2/3 of maximum value? **(-0.5 if answer is yes), AND**
			    o Did the oil inspection reveal any issues or particles above the limit? **(-0.5 if answer is yes)**
				1		

7.5.a For *electrical engine* applications, the UAS shall include means to minimize the risk of battery overheating / explosion	**Doc.**		The applicant shall deliver a document demonstrating the existence of systems means to minimize the risk of battery overheating / explosion for all batteries on board (powerplant + onboard systems): - Depending on the class and type of system: o Should the system have a means to measure battery temperature? IF YES Is the monitoring system adequate (cooling system, temperature sensor, Active battery management system) **(0 to 2)** Note Active bat. Man. Sys. Should be given the highest value. IF NO **(1)**	**2**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
7.5.b For *combustion engine* applications, the UAS design should consider ventilation, drainage, fuel lines, and tanks installation to minimize fire hazards.	**Doc.**		The applicant shall deliver a document demonstrating the existence of systems means to minimize the risk of battery overheating / explosion for all batteries on board: Depending on the class and type of system: - Should the system have a means to measure battery temperature? IF YES Is the monitoring system adequate (cooling system, temperature sensor, Active battery management system) **(0 to 1)** Note Active bat. Man. Sys. Should be given the highest value. The applicant shall deliver a document with a safety assessment addressing ventilation, drainage, fuel lines, and tanks installation to reduce fire hazards. Does the system show that there are physical barriers between fuel lines and tanks from electrical systems/batteries? **(0 to 0.5)**	**1.5**		
7.6.1.a For *electrical engine* applications, the UAS should have the means to measure the engine battery status (voltage, drown current, estimated battery time)	**Doc.**		The applicant shall deliver a document defining how the battery status is assessed **(0.5), AND** The system presents estimated flight time based on battery level **(0.5)**	**1**		
7.6.1.a1 For *electrical engine* applications, the UAS should include provisions to alert the UA operator that the battery has discharged to a level, which requires immediate UA recovery actions.	**Doc.**		The applicant shall deliver a document defining the function for issuing a warning for the battery charge critical level. Does the system have the means to alert UA operators of low battery? Yes= **(1)** No= **(0)**	**1**		
7.6.1.b For *combustion engine* applications, the UAS should include	**Doc.**		The applicant shall deliver a document defining how the fuel quantity measurement is made:	**1**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
means to measure the UAS fuel quantity during the whole mission.			- direct **(1)**; **OR** - calculated from fuel flow **(0.5)**			
7.6.1.b1 For *combustion engine* applications, the UAS should include provisions to alert the UA operator the fuel quantity has reached a level, which requires immediate UA recovery actions.	**Doc.**		The applicant shall deliver a document defining the function for issuing a warning for the fuel quantity critical level. Does the system have the means to alert the UA operator that the fuel level requires immediate action? Yes= **(0.5)** No= **(0)**	**0.5**		
7.6.1.b2 For *combustion engine* applications, the UAS should include means to provide the operator with information about fuel quantity.	**Doc.**		The applicant shall deliver a document defining the function for providing (continuously and permanently) to the operator the fuel quantity. Does the system have the means to inform UA operators of fuel level status? Yes= **(0.5)** No= **(0)**	**0.5**		
7.6.2 The UAS should include means to mitigate the hazards from engine failures.	**Doc.**		The applicant shall deliver a document as a safety analysis demonstrating how engine failures effects are mitigated. Namely, the assessment should consider: - There is a strategy to manage the loss of power, executed by the operator using checklists. **(0.5), AND** - There is a strategy to manage the loss of power, executed automatically by the system. **(1), AND** - Is the increase in workload compatible with operator training and experience? **(0.5)**	**2**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
			If there is no power loss risk mitigation strategy. **(0)**			
8. SYSTEM AND EQUIPMENT						
8.1 The UAS critical equipment should be qualified for worst expected case environmental conditions according to the design spectrum.	**Doc.**		1) Are all UAS critical equipment qualified for the worst expected case environmental conditions following the design spectrum? Yes=**(0 to 1.5), AND** Are there datasheets and reports confirming the qualification of the system? Yes=**(0.5)** **OR** 2) Are the UAS critical equipment tested for environmental conditions? Yes=**(0 to 1), AND** Are there datasheets of the equipment? Yes=**(0.5)** OR 3) Is there an analysis regarding the environmental conditions? Yes=**(0 to 1)**	**2**		
8.1.1 The UAS installation provisions and the intended usage of all equipment should be designed under the qualification conditions.	**Doc.**		The applicant shall deliver a document demonstrating how the environmental conditions were included in the design. This can be made (for example) through a Safety analysis with a specific risk assessment of the humidity, operating temperatures, ice conditions, etc. - Was the hazard of humidity considered in the design (Safety analysis)? Yes=**(0.5), AND** - Was the hazard of temperature, including icing conditions considered in the design? Yes=**(0.5)**	**1**		
8.2 The UAS must account for electromagnetic Effects (E) in the design	**Doc.& Test**		The applicant shall provide documentation that supports qualification and/or design features of the UAS that account for the Environmental Electromagnetic Effects (E3) The applicant shall define in UAS documentation all required operation	**2**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
			limitations regarding E3. - A statement referring that testing and experience has posed no limits **(1), AND** - Limits that cause no limitation for desired operation **(0.5), AND** - Limits that penalize operation **(0.5)**			
8.3 The UAS electrical design should be robust and designed to function in the worst foreseen conditions.	**Doc.**		Did the applicant provide documentation that supports the adequate design of electrical systems? Yes=**(0.2)**	**2**		
8.3.1 The UAS electrical capacity generation must be adequate for the intended use.	**Doc.& Test**		The flight manual must specify the maximum flight endurance. A test must be performed without failure of the electrical system for at least 1.5 times the number of allowable hours, with all systems working. Is there test-based evidence that the electrical system sustained full 1.3 times the maximum flight endurance? No=**(0)** If Yes Is there test-based evidence that the electrical system sustained full 1.5 times the maximum flight endurance? Yes=**(1.8);** No=**(0.9)**			
8.4 The UAS should be designed to incorporate means for fault detection/fault isolation / fault management.	**Doc.**		The UAS design should incorporate a sufficient set of Built-In-Tests (BIT): - power-up self-test **(0.25), AND**	**3**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
			- computers check-sum **(0.125), AND** - (D)GPS receiver failure indication from power-up **(0.2), AND** - System health (processor, data packages, memory) **(0.2), AND** - Navigation solution **(0.1), AND** - Self-test or background BIT **(0.125), AND** - motherboard under-voltage detection **(0.5), AND** - temperature monitoring **(0.5)**			
8.4.1 The UAS should have procedures established to mitigate the effects of detected faults.	**Doc.**		The UAS should have procedures in place to respond to the faults identified by the system. The system responds to faults identified: - Automatically **(0.8), OR** - Through operator input **(0.5), OR** - Automatic with operator cross-check **(1)**			
8.5 The UAS is equipped with external lights	**Doc.**		Lights are designed and installed following a recognised industry standard **(1), OR** Lights are demonstrated to be adequate for the approved operational environment **(0.5)**	**1**		
9. SAFE DEMONSTRATION						

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance		Max total Score	SCORE	RATIONALE
9.1 The UAS design should include Functional Hazard Analysis and a Failure Mode Effect and Criticality Analysis for the critical functions.	**Doc.**		All failure modes should be identified. The failure mode analysis should address: - The UAS platform, including actuators, powerplant, lift surfaces surfaces/devices, wheels/landing gear **(1), AND** - UCS/UCB, including autopilot, sensors, IMU, control boards, central processing computer, cables to actuators **(1), AND** - Data Link and any other equipment necessary to operate the UAS), including data link module (RF module), cables to antennas, and antennas **(1)**		**3**		
9.2 The UAS design should incorporate mitigations established for all failure modes identified.	**Doc.**		Are all failure modes identified? **(1), AND** Are respective mitigation strategies established and documented? **(1)**		**2**		
10. SOFTWARE AND ELECTRONIC HARDWARE DEVELOPMENT ASSURANCE							
10.1 The applicant should deliver a safety assessment to identify all the software critical functions of the UAS for the lifecycle, including flight control, propulsion, electrical power, etc. **10.1.1 The applicant should deliver documented life cycle assurance processes to deal with the SOFTWARE UAS critical functions.** **10.1.2 Software integrity should be**	**Doc.**		If weight < 4Kg **(5)** + following questions x 0.3; If weight < 25kg **(3.75)** + following questions x 0.5; If weight < 150kg **(2.5)** + following questions x 0.6; If weight > 150kg **(0)** + scores given by DO-178 DAL compliance. If the applicant delivers a safety assessment to identify all the software critical functions of the UAS for the lifecycle,including flight control, propulsion, electrical power, etc. **(1.5), AND**	**NOTE:** If software development is demonstrated per DO-178 objectives: For software that may lead to catastrophic failures: **(7.5)** for compliance or equivalency with DO-178			

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance		Max total Score	SCORE	RATIONALE
considered in the design of the UAS.			If the applicant delivers documented life cycle assurance processes to deal with the SOFTWARE UAS critical functions. **(2)** ******************************* For Software development, the applicant should demonstrate that: - requirements for software items are developed; **(0.5), AND** - plans and Accomplishment Summaries to show software integrity are produced by the design organization; **(0.5), AND** - an adequate number of tests is planned, performed and results are recorded; **(1), AND** - software problem reports are available and shown to be closed; **(0.5), AND** - configuration management processes for software are established and followed; **(1), AND** - in-filed experience as applicable; **(0.5)**	DAL B; **(2.5)** for compliance or equivalency with DO- 178 DAL C; **(3.5 *)** **(penalty up to -10 to be applied in the next step)** for compliance or equivalency with DO- 178 DAL D. **(0 *)** Notes: The above scores are assigned to lower DAL levels if the worst credible effect is classified as hazardous or major (e.g. 7.5 for DAL C for hazardous effects). If there is no evidence of software life cycle	**7.5**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance		Max total Score	SCORE	RATIONALE
				assurance processes, a penalty on the total score of 100 up to -50 may be assigned. ***** Extensive in-field experience with the same software configuration may be considered as a credit to increase the scores above if used with an adequate occurrence reporting system for problem report collection.			
10.2 The applicant should deliver a safety assessment to identify all the electronic hardware critical functions of the UAS for the lifecycle, including flight control, propulsion, electrical power, etc.	**Doc.**		If weight < 4Kg **(5)** + following questions x 0.3; If weight < 25kg **(3.75)** + following questions x 0.5; If weight < 150kg **(2.5)** + following questions x 0.6; If weight > 150kg **(0)** + scores given by ED-80 or DO-254 DAL compliance.	**NOTE:** If hardware development is demonstrated per ED-80 or DO-254 objectives: For hardware	**7.5**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance		Max total Score	SCORE	RATIONALE
10.2.1 The applicant should deliver documented life cycle assurance processes to deal with the ELECTRONIC HARDWARE UAS critical functions. **10.2.2 Electronic hardware integrity should be considered in the design of the UAS.**			If the applicant delivers a safety assessment to identify all the electronic hardware critical functions of the UAS for the lifecycle,including flight control, propulsion, electrical power, etc. **(1.5), AND** If the applicant delivers documented life cycle assurance processes to deal with the ELECTRONIC HARDWARE UAS critical functions. **(2)** ******************************* For electronic hardware development, the applicant should demonstrate that: - requirements for hardware items are developed; **(0.5), AND** - plans and Accomplishment Summaries to show hardware integrity are produced by the design organization; **(0.5), AND** - an adequate number of tests is planned, performed and results are recorded; **(1), AND** - hardware problem reports are available and shown to be closed; **(0.5), AND** - configuration management processes for hardware are established and followed; **(1), AND** - in-filed experience as applicable; **(0.5)**	that may lead to catastrophic failures: **(7.5)** for compliance or equivalency with ED-80 or DO-254 DAL B; **(2.5)** for compliance or equivalency with ED-80 or DO-254 DAL C; **(3.5 *)** **(penalty up to -10 to be applied in the next step)** for compliance or equivalency with ED-80 or DO-254 DAL D. **(0 *)** Notes: The above scores are assigned to lower DAL levels if the worst credible effect is			

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
			classified as hazardous or major (e.g. 7.5 for DAL C for hazardous effects). If there is no evidence of electronic hardware life cycle assurance processes, a penalty on the total score of 100 up to -50 may be assigned. * Extensive in-field experience with the same electronic hardware configuration may be considered as a credit to increase the scores above if used with an adequate			

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance		Max total Score	SCORE	RATIONALE
				occurrence reporting system for problem report collection.			
11. CONTINUING AND CONTINUED AIRWORTHINESS							
11.1 The applicant shall provide the UAS Flight Manual, with all the approved standard operating and emergency procedures.	**Doc.**		The applicant shall provide the Flight Manual for evaluation. The operational procedures in the Flight Manual shall include (as applicable) take-off, launch, climb, descent, glide, flight in all operating modes, landing, recovery, handover, autorotation, link-loss procedures, transportation and storage, etc). The UAS Flight Manual shall define all the operating procedures, limitations, and performance information for normal operations and emergency conditions. Does the flight manual provide all standard operating and emergency procedures? Attention to: All operating modes, landing, recovery, handover, autorotation, link-loss procedures, transportation and storage **(0.5), AND** Is the flight manual written in English in an unambiguous way? **(0.5)**		**1**		
11.2 The UAS Flight Manual shall be clear, unambiguous, and written in the English language.	**Doc.**						
11.3 The applicant shall provide the maintenance manual with all necessary instructions for ensuring continuing airworthiness.	**Doc.**		Was a Maintenance Manual delivered with the system? No=**(0)**; Yes=**(0 to 1)** <u>Attention to:</u> - life-limited parts, equipment inspection intervals, and techniques, equipment standard repairs and maintenance, corrosion prevention, etc. - All UAS systems and sub-systems, including the propulsion system, airframe, electrical system, fuel system, lubrication system, avionics, sensors calibration, actuators, communication system, ground station;		**1**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
			- Transport and handling information - Airframe inspection intervals and techniques are described adequately in the flight manuals; - Identification of the airframe repairs standard. - Health tracking monitoring equipment and procedures of safety-critical systems. - Specification of safe storage conditions. - Identification of corrosion-related inspections.			
11.4 The applicant should provide a pre-flight checklist and a post-flight checklist.	**Doc.**		Is there a Pre-flight Checklist? **(0.5), AND** Is there a Post-flight Checklist? **(0.5)**	**1**		
11.5 The applicant should provide a training syllabus by the complexity of the UAS operation and maintenance.	**Doc.**		If UAS MTOM < 4Kg Yes=**(1);** No=**(0)** If UAS MTOM < 25kg Yes=**(1);** No=**(0)** If UAS MTOM ≥ 25kg Yes=**(1)**; No=**(-5)**	**1**		
11.6 The UAS maintenance manual or equivalent document shall be complete and identify the qualifications for each type of inspection, maintenance, and repair	**Doc**.		Does the maintenance manual or equivalent document identify the qualification requirements for performing the inspections? **(0.8), AND** Does the maintenance manual or equivalent document identify the	**1**		

Requirement	Proof of Evidence	Remarks	Partial Score applicable to the Method of Compliance	Max total Score	SCORE	RATIONALE
required			qualification requirements for maintenance and repair? **(0.2)**			
11.7 The applicant should demonstrate to have a method to track technical occurrences (that have been reported) affecting safety throughout the life of the program.	**Doc.**		Did the applicant deliver a process to manage tracking occurrences throughout the lifecycle of the UAS? **(0.5), AND** Is the method defined for answering reported technical occurrences robust regarding the implementation of preventive measures and corrective actions for future developments or improvements of the system? **(0.5)**	**1**		
11.8 The applicant should demonstrate to have a method to implement preventive and corrective actions as necessary to continuously improve airworthiness.	**Doc.**					

C.1.2 Correction matrix

The DIAC is designed to obtain a maximum score of 100 points. However, the DIAC does not consider the relationship between the different areas, and how failing to comply with one of them may affect the others. Therefore, it is necessary to apply a correction factor matrix to reduce the score of specific domains with cross-domain items whose absence will have a negative impact on the reliability of that domain. The definition of the correction factor matrix combines the influence of relevant items addressed in the UAS assessment with the results of the DIAC for each domain. The relevant items are reported in the following table with their applicability:

Domain	DIAC reference	Applicability
1. No Quality Assurance System including Technical Occurrence Tracking	Question 1.1 score = 0 Question 11.1 and 11.2 score = 0	Always apply the correction
2. No DO Configuration Management	Question 1.5 score = 0	Always apply the correction
3. Human Machine Interface not adequately considered	Sum of score on section 5 < 2.5	Always apply the correction
4. No adequate evidence of Structural Integrity	Sum of score on section 6 < 3	Apply the correction if the DIAC score is > 35
5. No adequate evidence of Propulsion Integrity	Sum of score on section 7 < 3	Always apply the correction
6. Inadequate E3	Question 8.2 score < 2	Always apply the correction
7. The applicant did not provide an FTA for the UAS cumulative probability of uncontrolled flight/crash	N.A.	Apply the correction if the DIAC score is > 50 **AND** UAS MTOM > 4kg
8. No adequate Software and/or Hardware Life Cycle Assurance	Sum of score on section 10.1 < 6 **OR** Sum of score on section 10.2 < 6	Apply the correction if the DIAC score is > 44
9. No adequate instructions for Cont. AW	Sum of score of section 11 < 5	Always apply the correction

The impact coefficients values regarding their classification are the following:

- **No impact** – **1** - This means that there is no relationship between the two domains and that failing to comply with one of the above items will not have any impact on other domains.
- **Medium impact – 0.8 (small)** – This means that failing to comply with one of the above items will have a limited impact on the related domains, which is accounted for by multiplying the score obtained in the DIAC for that domain by 0.8;
- **High impact – 0.6 (big**) - This means that failing to comply with one of the above items will have a significant impact on the related domains, which is accounted for by multiplying the score obtained in the DIAC for that domain by 0.6;
- **Explicit – 0** - Failing to comply with one of the above items means that one of the domains have not been properly evaluated and therefore its score is cancelled from the total DIS.

For example, if there is no quality assurance system, the score obtained in the Continued Airworthiness area will need to be lowered by multiplying it for 0.6.

The matrix of impact coefficient values is illustrated in the Figure below.

	Organization	Adopted Design Standards	Tested Usage Spectrum	Stab Control / Nav Perfomance & Emergency Cond.	Ground Control Station	Structural Integrity	Propulsion Integrity	System Integrity	Safety Demonstration	Software/Hardware Integrity	Continued / continuing Airworthiness
1. Quality Assurance System including Technical Occurance Tracking	1	0.8	0.6	0.8	0.8	0.6	0.6	0.6	0.6	0.6	0.6
2. DO Configuration Managment	1	1	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1
3. Human Machine Interface	1	1	1	1	1	1	1	1	0.8	1	0.6
4. Structural Integrity	1	0.8	1	1	1	1	1	1	1	1	0.6
5. Propulsion Integrity	1	0.8	1	1	1	1	1	1	1	1	0.6
6. Inadequate E3	1	0.8	0.8	0.8	1	1	0.8	0.8	1	1	0.8
7. No FTA	1	1	1	0.6	1	1	0.6	1	1	1	0.6
8. Software and/or Hardware Life Cycle Assurance	1	0.8	1	0.6	0.8	1	0.8	1	1	1	1
9. Instructions for Cont AW	1	1	1	0.6	0.6	0.6	0.6	0.6	0.8	0.6	1

Figure 6: DIAC correction matrix

C.1.3 Final Design & Integrity Score (DIS) correction

In this sub-step the final score obtained after applying the correction matrix may need to be further reduced if mandatory requirements are not fulfilled. The following table reports the maximum scores allowed depending on the fulfilment of mandatory requirements.

Requirement	DIAC reference	Applicability	Penalty	EVIDENCE
HMI and workload aspects shall always be addressed	Score assigned to question 5.1 shall be 1	All UAS models and operational environments	**-5** from the score obtained after the correction matrix	
The applicant is required to demonstrate by the test that the UAS is safe when in operation within the established limitations. This test must include ground station, datalink equipment, air vehicle, etc.). If failures or inadequate E3 behaviour occurs during a demonstration	Score assigned to question 8.2 shall be 2	All UAS models and operational environments	**-20** from the score obtained after the correction matrix	
The applicant must provide an FTA for the UAS cumulative probability of uncontrolled flight/crash.	N.A.	All UAS with MTOM > 4kg	If the FTA is not done, the maximum achievable score for the UAS is computed as follows, considering the number of safety-critical systems that are fail-safe and/or the safety-critical system failures that are mitigated Max achievable score will be calculated as: Score = 100 - [20+(60/num_of_critical_sys) *num_of_non_redundant_sys] * ClassFactor With reference to weight classes: - weight <25kg ClassFactor = 1/8; - weight <150kg ClassFactor = ¼;	

			- weight >150kg ClassFactor = 1;	
The maximum score should be aligned with the cumulative probability of uncontrolled flight/crash of the UAS	N.A.	The applicant shall provide the cumulative probability of uncontrolled flight/crash if the total score after the correction matrix is > 66	If the Probability of failure is bigger than 10-4 the maximum achievable score is computed as follows: $$Max\ score = -\frac{\ln(10P_{cat})}{0.069}$$	
Software development must be demonstrated per DO-178 objectives: • **For software that may lead to catastrophic failures compliance or equivalency with DO-178 DAL C is required.** • **For software that may lead to hazardous failures compliance or equivalency with DO-178 DAL D is required.** *Extensive in-field experience with the same software configuration may be considered equivalent to DAL D.*	Questions 10.1	All UAS with MTOM > 150kg	**-10** from the score obtained after the correction matrix if compliance or equivalency with lower DAL level is demonstrated. **-25** from the score obtained after the correction matrix if there is no evidence of software life cycle assurance processes	
Electronic hardware development must be demonstrated per ED-80/DO-254 objectives: • **For Electronic hardware that may lead to catastrophic failures compliance or equivalency with ED-80/DO-254 DAL C is required.** • **For Electronic hardware that may lead to hazardous failures compliance or equivalency with ED-80/DO-254 DAL D is required.** *Extensive in-field experience with the same electronic configuration may be considered equivalent to DAL D.*	Questions 10.2	All UAS with MTOM > 150kg	**-10** from the score obtained after the correction matrix if compliance or equivalency with lower DAL level is demonstrated. **-25** from the score obtained after the correction matrix if there is no evidence of electronic hardware life cycle assurance processes	
The applicant shall provide the maintenance manual with all necessary instructions for ensuring continuing airworthiness.	Answer to question 11.3 must be Yes	All UAS models and operational environments	**-10** from the score obtained after the correction matrix	
The applicant shall manage reported technical occurrences	Total score for questions 11.7 and 11.8 must be 1.	All UAS models and operational environments	**-5** from the score obtained after the correction matrix	

C.2 Operational Checklist

Operational Checklist enables the Operational Unit to determine if the DIS of the UAS selected for the mission needs to be lowered or not. The DIS of the UAS has been defined assuming that:

- The UAS will always fly in an operational environment for which it is designed
- The operator possesses the required competencies and procedures to effectively manage the UAS operation
- The personnel possess all required qualifications to safely execute the mission
- All externally provided services are adequate for the intended mission.

To evaluate the above points the operational unit carries out a self-assessment checklist. Providing the evidence referenced in the checklist may not be always mandatory. The expectation is that compliance will need to be demonstrated for cross-border operations while this may not be necessary otherwise.

This questionnaire is composed of several questions covering the following area:

A. Competences of the Remote Flight Crew
B. Mission-planning aspects
C. Blast/impact containment system (if the carriage of explosives is foreseen)
D. Operational procedures
E. Operator’s competence
F. External services

For each of the six areas above, a negative answer to one or more of the questions leads to a reduction of the DIS of the UAS selected for the mission according to the table below:

	Organization	Adopted Design Standards	Tested Usage Spectrum	Stab Control / Nav Accuracy & Emergency Cond.	Ground Control Station	Structural Integrity	Propulsion Integrity	System Integrity	Safety Demonstration	Software Integrity	Continued / continuing Airworthiness
No evidence of operational procedures	1	1	0.5	0.5	0.5	0.5	0.5	0.5	1	1	1
No evidence of remote crew training	1	1	0.5	0.1	0.1	0.5	0.5	0.5	1	1	1
No evidence of external service SLA	1	1	0.5	0.5	1	1	1	1	1	1	1
No evidence of *maintenance* organisation and competences at operator's level	1	1	1	0.1	0.1	0.5	0.5	0.5	1	1	0.5
No evidence of Blast/impact	1	1	0.5	0.5	1	0.5	1	0.5	0.1	0.5	0.5
No evidence of mission-planning aspects	1	1	0.1	0.5	0.5	1	1	1	0.1	1	1

Figure 7: Operational questionnaire correction matrix

The correction factors were defined using expert judgment and can be adapted by EDA pMS. The factors used are as follows:

- **0.1** means that the corresponding score obtained in the DIAC in Step#A is reduced by a factor of 10. This implies a significant impact on the related domain. For example, the absence of adequate remote crew training for the UAS selected for the mission may severely affect the capability of the crew to properly manage the UAS thus affecting the management of emergency conditions and navigation performance.
- **0.5** means that the corresponding score obtained in the DIAC in Step#A is reduced by half. This implies a major impact on the related domain. For example, the absence of adequate operational procedures may affect the capability of the crew to maintain the UAS within its Tested Usage Spectrum thus affecting the evaluation carried out by the NMAA.
- **1** means that the corresponding score obtained in the DIAC in Step#A is not affected.

The tables below report the questions for each of the 6 areas.

Question Number	Question or area	Supplemental Information	Evidence
(A) Competences of the Remote Flight Crew (RFC)			
Training			
A.1	Is there a periodically updated Training Syllabus to demonstrate that the Remote Flight Crew (RFC) is adequately trained for the planned operation and ensures knowledge of at least the following topics: 1 - the NMAA Regulation for UAS operations; 2 - National Airspace and Military Airspace; 3 - Airspace operating principles; 4 - Aviation safety; 5 - Human performance limitations; 6 - Meteorology; 7 - Navigation/Charts; 8 - UAS (system, flight mechanics, structure); 9 - Military operational procedures;	The Remote Flight Crew (RFC) is meant as the set of people involved in the operation and should have specific theoretical and practical training on their duties (e.g. preparation of the launch site, pre-flight inspection, ground equipment handling, flight conduction, preparation of the meteorological bulletins, etc.).	
Human Error			
A.2	Is the Remote Flight Crew subject to periodic health checks (mentally and physically) to demonstrate that they are fit to operate?	A medical standard considered adequate by the NMAA can be specified.	
A.3	Is there a policy defining how the Remote Flight Crew must be fit to operate before conducting any operation?		
A.4	Is there a policy defining how to manage the fatigue and stress of the Remote Flight Crew to reduce human error (e.g., rest periods, remote flight crew duty times, operational breaks, the composition of the Remote Flight Crew)?		
A.5	Does the Remote Flight Crew receive Crew Resource Management (CRM) training?	The CRM training aims to train the Remote Flight Crew on how to reduce potential human errors and avoid stress. It allows the Remote Flight Crew to ensure the safety and effectiveness of the operation.	
(B) Mission-planning aspects			
Operational volume			
B.1	Is the Operational volume defined taking into account the following elements? - Maximum dimension of the operational volume - Location (coordinates) - Topography and main obstacles (if any) - Failures or malfunctions of the propulsion system; - Meteorological conditions;		

	- Possible interferences; - UAS performance; - Dangerous payload (if any); - UAS latencies.		
B.2	How is the population density in the operational area evaluated?	The population density can be established by using authoritative density data	
B.3	Is the shelter factor considered in the assessment of the Ground Risk? If yes, which parameters are used to compute it?	The shelter factor can be established by using authoritative density data	
	Adjacent area		
B.4	Is the adjacent area defined taking into account the following elements? - Adjacent area extension; - Population density in the adjacent area; - Topography and main obstacles (if any); - Shelter factor in the adjacent area.		
	Environmental conditions evaluation		
B.5	Is the operation planned in meteorological conditions (e.g., CAVOK, drizzle, snow, haze, other severe adverse weather conditions, etc.) that are outside the design limits of the UAS?		
B.6	Are there procedures for evaluating ongoing and foreseen meteorological conditions on the operational volume and in the adjacent area?	These procedures could include the reading of METAR, TAF, MET-REPORT, NOTAM, etc.	
	Critical infrastructure (if included in the operation)		
B.7	Is the operation planned to overfly critical infrastructures (E.g., missile launch sites) that could lead to interferences in the C2 link? If yes, is this event addressed by the operational procedures?		
B.8	How the interferences produced by critical infrastructures are evaluated?		
	Operation of multiple UAS (if included in the operation)		
B.9	Are there other UAS flying in the same area? Is the interference on the C2 link been evaluated and proper mitigations identified?		
	(C) Blast/impact Containment system (if included in the operation)		
	Transport of Dangerous Goods (e.g., Blast Containment System, Crash-Proof Container)		
C.1	Does the operation include the transport of Dangerous Goods? If so, which one(s)?	For operations including the transport of dangerous goods (ICAO Doc 9284), depending on the type of payload a crash-proof container and/or a Blast containment system could be required	

C.2	In case of dangerous goods transports the crash-proof container and/or the blast containment system certified as adequate to the carried payload? Is there a manufacturer's release note specifying the features and limitations of the container/containment system?		
C.3	How is the effectiveness of the systems/means to contain the effects of ground impact assessed?	In the case of explosive payload, a higher risk is faced and could also impact the shelter factor	
C.4	Is the *Flight Remote Crew* trained in the systems and any related operational functions? Are these aspects covered and clearly defined in the Training Syllabus?	See question A.1 for the Training Syllabus	
C.5	Is the *personnel responsible for installation and maintenance* trained and are these aspects covered in the training syllabus?	See question E.3 for the Training Syllabus	
C.6	Is the equipment used to contain the impact installed and maintained according to the manufacturer's instructions? Are there procedures on how to prepare, load, and unload the payload? Is a checklist related to these procedures available?		
Systems to reduce effects of ground impact (e.g., Parachute)			
C.7	Is the *Remote Crew* trained in the systems and any related operational functions? Are these aspects covered and clearly defined in the Training Syllabus?	See question A.1 for the Training Syllabus	
C.8	Is the *personnel responsible for installation and maintenance* trained and are these aspects covered in the training syllabus?	See question E.3 for the Training Syllabus	
C.9	Is the equipment used to reduce the impact installed and maintained according to the manufacturer's instructions?		
(D) Operational procedures			
Procedures in normal operation condition			
D.1	Are procedures in a normal operating condition defined and do these procedures take into account the following elements? - Mission planning (NOTAMs, weather reports, weather forecast, airspace availability, segregated airspace request, etc); - Preparation of the mission equipment; - Preparation of the launch site; - Preparation of the UAS; - UAS status and operational correctness check (Pre-flight check); - Take-off; - Preparation for landing; - Landing; - After landing; - UAS and equipment secured.		
D.2	Are checklists for normal operation condition procedures available for the Remote Fight Crew (RFC)?		
D.3	Is the Remote Flight Crew trained for normal operation condition procedures and are these considered in the Training Syllabus?	See question A.1 for the Training Syllabus	

Emergency Procedures			
D.4	Are emergency procedures established and do these procedures take into account the following elements? - UAS leaving the operational volume - Failure of the propulsion system; - Hijacking; - Unacceptable weather conditions; - UAS or Remote Flight Crew under attack.		
D.5	Are checklists for emergency procedures available for the Flight Remote Crew (RFC)?		
D.6	Is the Remote Flight Crew trained for emergency procedures and are these considered in the training syllabus?	See question A.1 for the Training Syllabus	
Multi-crew operations (if included in the operation)			
D.7	Is the crew adequately trained for multi-crew coordination and is this aspect covered in the Training Syllabus?	See question A.1 for the Training Syllabus	
D.8	Are the multi-crew coordination procedures established (e.g., crew tasks, communications protocol, the establishment of communications)?		
Handover (if included in the operation)			
D.9	Is the crew adequately trained for handover procedures and are those aspects covered in the Training Syllabus?	See question A.1 for the Training Syllabus	
D.10	Are the handover procedures for the intended operations established?		
Operations from moving platform (if included in the operation)			
D.11	Is the pilot adequately trained on procedures for UAS operations from the moving platform and is this aspect covered in the Training Syllabus?	See question A.1 for the Training Syllabus	
D.12	Are the procedures for UAS operations from moving platforms established?		
Simultaneous Operation with UAS and/or with manned aircraft/helicopter (if included in the operation)			
D.13	Is the crew adequately trained for simultaneous operation with UAS and/or with manned aircraft/helicopter and is this aspect covered in the Training Syllabus?	See question A.1 for the Training Syllabus	
D.14	Are the procedures for simultaneous Operation with UAS and/or with manned aircraft established?		
(E) Military UAS Operator's competence			
Organisation			
E.1	Is the Structure of the Organisation (operations, maintenance, quality, and safety) included in the Operations Manual?		
E.2	Are the roles, responsibilities, and duties of the *flight planning staff* clearly defined?		
E.3	Are the roles, responsibilities, and duties of the *Remote Flight Crew* clearly defined?		
E.4	Are the roles, responsibilities, and duties of the *Maintenance staff* clearly defined?		
E.5	Are the roles, responsibilities, and duties of the *staff authorised to manipulate dangerous goods* (e.g. explosives) clearly defined?		
E.6	Are there periodically updated Training Syllabus to demonstrate that the flight planning staff, maintenance personnel, and personnel authorised to manipulate dangerous goods are adequately trained for the planned duties and ensure knowledge and practical skills to execute respective tasks?		

E.7	Are there records of training and qualification of the Remote Flight Crew, of the Maintenance staff, or the flight planning staff and the personnel manipulating dangerous goods?		
E.8	Are maintenance procedures, covering at least the UAS manufacturer instructions and requirements, defined?		
E.9	Are there procedures to ensure that the tools & instruments used in maintenance tasks are in accordance with the UAS manufacturer requirements (e.g. calibration, life limit)?		
E.10	Are there procedures to ensure that materials and spare parts used in maintenance tasks are per the UAS manufacturer requirements and are properly stored?		
	(F) External services		
F.1	Are there procedures to ensure that the level of performance for any externally provided service necessary for the safety of the flight is adequate for the intended operation?		
F.2	Are the roles and responsibilities between the UAS operator and the commercial external service provider clearly defined (e.g. in a Service Level Agreement - SLA)?		
F.3	Are there procedures to continuously monitor the performance of the externally provided services?		

C.3 Containment score (CS)

C.3.1 Containment Assessment Checklist (CAC)

Containment Assessment checklist allows for evaluating of the performance of the containment system. Examples of containment systems include:

- Flight Termination Systems
- Geo-caging functions

The intrinsic capability of the UAS to remain within the operational volume is out of the scope of this questionnaire as it is evaluated through the Design and Integrity Assessment Checklist.

The Containment Assessment checklist takes SORA Step#9 and SC-Light.UAS.2511 as the references.

Question Number	Question or area	Score range	Method of compliance
C.1	The system used for containment shall be independent and dissimilar from the main Flight Control System. The UAS backup energy system shall allow for UAS recovery and/or safe flight termination for the duration defined by the flight manual.	This is a pre-requisite that must be always fulfilled.	*Design and installation appraisal that includes at least the following elements are available:* *- design of the features (independence, separation, and redundancy);* *- installation of the containment system* *- relevant risk related to the operation (e.g., severe snow, ice, etc.)* *A test demonstration must be made for UAS recovery and/or safe flight termination with only the backup energy system.*
C.2.1	Were tests and analyses conducted to demonstrate that the UAS containment system is not likely to experience probable failures that may lead to an operation outside the operational volume?	0-3	*Tests reports available demonstrate a reliability of the containment system that is commensurate with the DAL level used for SW and AEH development assurance.* *The scores can be assigned as follows:* • *Demonstrated reliability < 10^{-2}* ***[1]*** • *Demonstrated reliability < 10^{-3}* ***[2]*** • *Demonstrated reliability < 10^{-4}* ***[3]***
C.2.2	Are the Software (SW) and Airborne Electronic Hardware (AEH) of the containment system developed against a standard recognised by the NMAA?	0-1	*SW is developed according to ED-12C or DO-178C, DAL D if the score assigned to C2.1 is 3* ***[0.5]*** *AEH must be developed according to ED-80 or DO-254, DAL D if the score assigned to C2.1 is 3* ***[0.5]***
C.3	Is the system used for containment designed and tested according to a recognised standard or AMC (e.g. EASA MoC Light-UAS.2511)? If yes, what is the reliability level ensured by the chosen standard?	0-6 depending on the design standard	*Points are obtained only if a recognised standard is used (e.g. EUROCAE ED-270). Then score is assigned depending on the reliability of the system.*

N.B.: Questions C.1 and C.2 must be considered if no recognised standard for the design and development of the containment system is used.

C.4 Air Risk Mitigations

Air risk Mitigations enable the Operational Unit to apply mitigations (tactical and strategical) to lower the initial TCR.

Each mitigation has an assigned ARMS (Air Risk Mitigation Score). The operational unit could apply one or more mitigations by demonstrating their effectiveness through evidence.

Question Number	Applicable mitigation / question	ARMS	Supplemental Information	Evidence
NOTE:	This is the Mitigations application questionnaire. To fill up the questionnaire the operator has to be fully familiar with the Air Risk Assessment process detailed by MUSRA. Once determined the Operational Environment of the operation and its TCR level, the operator can proceed to lower the TCR by applying strategic and tactical mitigations. Mitigations application has to be demonstrated through evidence.			
	Time of Exposure			
M.1	What mean(s) is applied to reduce the time of exposure to the risk and what is the impact on the latter? Are the following parameters taken into account: - evaluation of the operational risk (E.g., frequency of take-off/landing of aircraft, the density of air traffic in the operational volume, etc.); and - definition of the procedures to reduce the time of exposure.	18	Time of exposure mitigations can be considered as a means to reduce/limit the time of exposure to an operational risk (e.g., short-time UAS operation in the proximity of a civil ATZ, flying on the edge of a busy environment, etc).	
	Day/time of the operation			
M.2	When does the UAS operation take part and how can it affect the risk of the mission? Are the following parameters taken into account: - evaluation of the operational risk (E.g., frequency of take-off/landing of aircraft on a specific day/time, the density of air traffic in the operational volume on a certain day/time, etc.).	18	Day/time of operation can be considered as a means to reduce/limit the encounter rate with aircraft (e.g., flying during a day when a low air traffic low is expected, flying at night, etc).	
	UAS transit routes/corridor			
M.3	Which UAS transit route/corridor shall be flown by the UAS during the operation? Are the following parameters taken into account: - operational characteristics of the UAS transit route/corridor (availability, dimensions, type of traffic allowed, operational limitations); and - definition of the procedures to fly the UAS transit route/corridor; and	30	UAS transit routes/corridors can be considered as means to reduce/limit the encounter rate with aircraft through the implementation of pre-defined corridors and/or routes known by other traffic (e.g., a corridor linking connecting the	

	- mandatory/optional requirements needed to fly the UAS corridor/transit route (if any).		aerodrome of departure to the CTR border and vice versa, etc.).	
	<u>Flight plan</u>			
M.4	Is a Flight Plan filed for the intended operation? Is the information about the planned flight expected to be distributed to other airspace users by ATC?	12	A flight plan allows other traffic to get information on the UAS operation: time, route, altitude, and any other useful information. Evidence might be a copy of the Operational Flight Plan	
	<u>Dangerous area</u>			
M.5	Is the area and characteristics of the operation notified by the issue of a NOTAM for "Dangerous Area"? Is the Dangerous area reserved for UAS operations only or does it allow other military activities?	6	A NOTAM (Notice To Airmen) might be issued to disseminate information about UAS operations in a specific volume of airspace.	
	<u>U-space strategical services</u>			
M.6	Which U-space service(s) is used for the intended operation? What is the expected impact on the operation when the U-space service(s) mitigation has been applied? Is the performance level of the U-space service assessed and guaranteed?	30	Uspace services might be applied. The effectiveness of this mitigation depends on the U-space service provided (i.e. flight authorization).	
	<u>Increased separations</u>			
M.7	Are there increased separations applied? What kind of increased separations are applied for the intended operation and how do they reduce the risk? Are the following parameters taken into account: - operational characteristics of the operational environment (airspace dimensions and class, operational limitations); and - definition of the increased separations procedures; and - requirements needed to cover the increased separations procedures.	15	Increased separations might be applied by ATC units to "enlarged" separations between manned and UAS traffic (double or more separation) in a certain volume of airspace.	
	<u>Coordination/Communications with ATS units</u>			
M.8	Do you implement coordination with the ATS unit? Do you implement communications with ATS unit? Are the following parameters taken into account: - ATS unit(s) involved in coordination; - definition of the impact of this mitigation on the operation;	12		

C.5 Minimum Detect-And-Avoid Requirements Checklist (MDARC)

MDARC contains all the Minimum Detect-And-Avoid Requirements (MDAR) to be met for carrying out the planned operation. These requirements are based on the overall technical performance, reliability, and integrity of the system(s) on which the Detect-and-Avoid capability is based. Once obtained the final TCR is, the Operational Unit shall demonstrate compliance with the requirements contained corresponding to the TCR of the airspace. Two different MDARC are proposed, one intended for the NMAA and/or the manufacturer of the UAS or the DAA system, the other for the OPU.

Operational Unit MDARC

Table 16: MDARC for the OPU

Question Number	Question or Minimum Detect-And-Avoid Requirements (MDAR)	Supplemental Information	Evidence
NOTE:	This is the Minimum Detect-And-Avoid Requirements Checklist (MDARC). To fill up the questionnaire the OPU has to be fully familiar with Air Risk Assessment process detailed in the "MIL-UAS-SPECIFIC D2 Methodology" document. Once determined the Final TCR, the operator can proceed to fill in this questionnaire to verify compliance with the MDAR. Compliance with MDAR has to be demonstrated through evidence.		
	TCR 4		
	VLOS/EVLOS	The operation is not allowed due to the high risk of this operational environment. It can only be performed with a certified UAS. The operator can apply strategical mitigations to lower the initial TCR.	
MR.1	Operation not allowed		
	BVLOS		
MR.2	Operation not allowed		
	TCR 3		
	VLOS/EVLOS		
MO.1	Is there a de-confliction scheme that explains how the detection is carried out, what criteria are applied to decide to start an avoidance maneuver and how this is implemented?		
MO.2	If an airspace observer is used to aid the pilot in detecting other traffic, Is there a phraseology protocol to be used among the Remote Flight Crew?		

MO.3	If the de-confliction scheme requires radio communication between Flight Crew members, is the maximum latency of the communications system less than 15 seconds?		
BVLOS			
MO.4	Is the UAS equipped with a DAA system that was assessed by the NMAA as adequate for TCR 3 environment?		
MO.5	Is the detection system used by the DAA able to detect at least 80% of the traffic in the detection volume?	Depending on the type of traffic that can be encountered some sensors maybe not effective. (e.g. Mode-S transponders in uncontrolled airspace.	
MO.6	Is there a de-confliction scheme that explains how the detection is carried out and what criteria are applied to decide to start avoiding incoming traffic?		
MO.7	Is there a phraseology protocol to be used during the support of the DAA system?		
M0.8	If the UAS is not equipped with any DAA system, are there U-space services that can effectively provide separation provision and collision avoidance functions? If yes, have they been assessed as adequate in terms of performance and availability?		
TCR 2			
VLOS/EVLOS			
MY.1	Is there a de-confliction scheme that explains how the detection is carried out, what criteria are applied to decide to start an avoidance maneuver and how this is implemented?		
MY.2	If an airspace observer is used to aid the pilot in detecting other traffic, Is there a phraseology protocol to be used among the Remote Flight Crew?		
MY.3	If the de-confliction scheme requires radio communication between Flight Crew members, is the maximum latency of the communications system less than 15 seconds?		
BVLOS			
MY.4	Is the UAS equipped with a DAA system that was assessed by the NMAA as adequate for TCR 2 environment?		
MY.5	Is the detection system used by the DAA able to detect most of the traffic in the detection volume?	Depending on the type of traffic that can be encountered some sensors maybe not effective. (e.g., Mode-S transponders in uncontrolled airspace.	
MY.6	Is there a de-confliction scheme that explains how the detection is carried out and what criteria are applied to decide to start avoiding incoming traffic?		
MY.7	Is there a phraseology protocol to be used during the support of the DAA system?		

MY.8	If the UAS is not equipped with any DAA system, what external service is used to detect other traffic (Monitoring aeronautical radio communication, relying on defence radar capability, U-space)? Is the system selected able to effectively provide awareness about most of the traffic in the detection volume? Is the Maximum Command-to-Execute latency not exceeding 5 seconds, and the Normal Command-to-Execute latency not exceeding 2 seconds? Is the UAS rate of descent at least 500 ft/min? Is the maximum latency for an intruder and own aircraft vector less than 10 seconds with a minimum update rate of 5 seconds? Is the failure probability of the external system lower than 1E-2/FH?		
TCR 1			
VLOS/EVLOS		It is not necessary to fulfill any MDAR in TR! category. Compliance with any MDAR is considered useful but has no to effect on the Risk Assessment.	
MG.1	Optional		
BVLOS			
MG.2	Optional		

National Military Airworthiness Authority MDARC

Table 17: MDARC for the NMAA

Question Number	Question or Minimum Detect-And-Avoid Requirements (MDAR)	Supplemental Information	Evidence
NOTE:	This is the Minimum Detect-And-Avoid Requirements Checklist (MDARC). This checklist only addresses DAA capability for BVLOS since for VLOS flights it is not necessary to rely on technical systems. Compliance with MDAR has to be demonstrated through evidence.		
TCR 4			

BVLOS			
MR.1	Operation not allowed		
TCR 3			
BVLOS			
MO.1	Is the DAA system capable of detecting 80% of all manned aircraft in the Detection Volume using one or more of the following systems? • On and/or off UAS sensors (i.e., EO/IR, Radar, etc) • ADS-B In aircraft trackers • Mode-S transponders • Ground-based radars		
MO.2	Has the installation and interface of the DAA system with the UAS been assessed as part of the Design and Integrity Assessment Checklist?		
MO.3	Has the human/machine interface and the tools and methods utilized for the timely detection and avoidance of traffic been assessed to demonstrate that the pilot can act upon detection of incoming traffic in less than 5 seconds?		
MO.4	Is the Maximum Command-to-Execute latency of the UAS not exceeding 3 seconds and the Normal Command-to-Execute latency not exceeding 1 second?		
MO.5	Is the UAS capable of the following minimum maneuver performance: ○ Minimum achievable airspeed: 50 Knots ○ Rate of climb/descend: ≥ 500 ft/min ○ Turn rate: ≥ 3 degrees per second		
MO.6	Are the update rate and maximum latency of the DAA system less than 3 seconds?	The required latency may be lower depending on the technology selected.	
MO.7	Is the failure probability of the DAA system been assessed through analyses, simulations, and/or flight tests to demonstrate that it is less than 5E-4/FH in all expected environmental conditions?		

TCR 2			
BVLOS			
MY.5	Is the DAA system capable of detecting most the other aircraft in the Detection Volume using one or more of the following systems? • On and/or off UAS sensors (i.e., EO/IR, Radar, etc) • (web-based) real-time aircraft tracking services • Low-Cost ADS-B In/UAT/FLARM/Pilot Aware aircraft trackers Ground-based radars	The detection volume is the volume of airspace (temporal or spatial measurement) which is required to avoid a collision (and remain well clear if required) with manned aircraft	
MY.6	Has the installation and interface of the DAA system with the UAS been assessed as part of the Design and Integrity Assessment Checklist?		
MY.7	Is the Maximum Command-to-Execute latency of the UAS not exceeding 5 seconds and the Normal Command-to-Execute latency not exceeding 2 seconds?		
MY.8	Is the UAS capable of the following minimum maneuver performance: ○ Rate of climb/descend: ≥ 500 ft/min		
MY.9	Is the update rate and maximum latency of the DAA system less than 3 seconds?		
MY.10	Is the failure probability of the DAA system been assessed through analyses, simulations and/or flight tests to demonstrate that it is less than 1E-2/FH in all expected environmental conditions?		
GREEN (TCR 1)			
SAA (See-And-Avoid)		It is not necessary to fulfil any MAA GREEN category. Compliance with any MAA is considered useful but has no effect on the Risk Assessment.	
MG.1	Optional		
DAA (Detect-And-Avoid)			
MG.2	Optional		

ANNEX D Additional Guidance

D.1 Population Density (PD)

This section outlines the process to accurately determine the population density for the assessment of the Ground Risk in MUSRA. The process is composed by two steps:

1. Determining the area to be considered for the assessment of the population density, i.e. the operational footprint
2. Identify an adequate representation of the population density.

D.1.1 Determining the operational footprint

The operational footprint contains the Operational Volume, and it may include a Ground Risk Buffer. The Operational Volume is made of:

- Flight geography: the volume within which the UAS mission is planned. Flight geography should be defined considering the overall accuracy in the UAS positioning, i.e. the Total System Error (TSE)
- Contingency volume: the volume outside the flight geography where contingency procedures are used to regain full control of the UAS. E.g. the volume within which the UAS may fly during a temporary loss of the C2 link.

Outside the operational volume the OPU may define a Ground Risk Buffer to cope for malfunctions or failures that could lead to an operation outside the Operational Volume. These failures would be handled by the containment systems to ensure the operation is terminated inside the Ground Risk Buffer.

D.1.2 Determining the population density

When determining the population density of the operational footprint two cases may arise:

1. The population density is homogenous, and a single value can be used for the whole operation
2. The population density is heterogeneous because the UA overflies different types of areas or because there are areas where there is a concentration of people inside the operational volume (e.g. in case of public events).

For case 1 the OPU should identify the population density using census data or other official sources. The figure below shows an example of a census data map where areas with different population densities are identified.

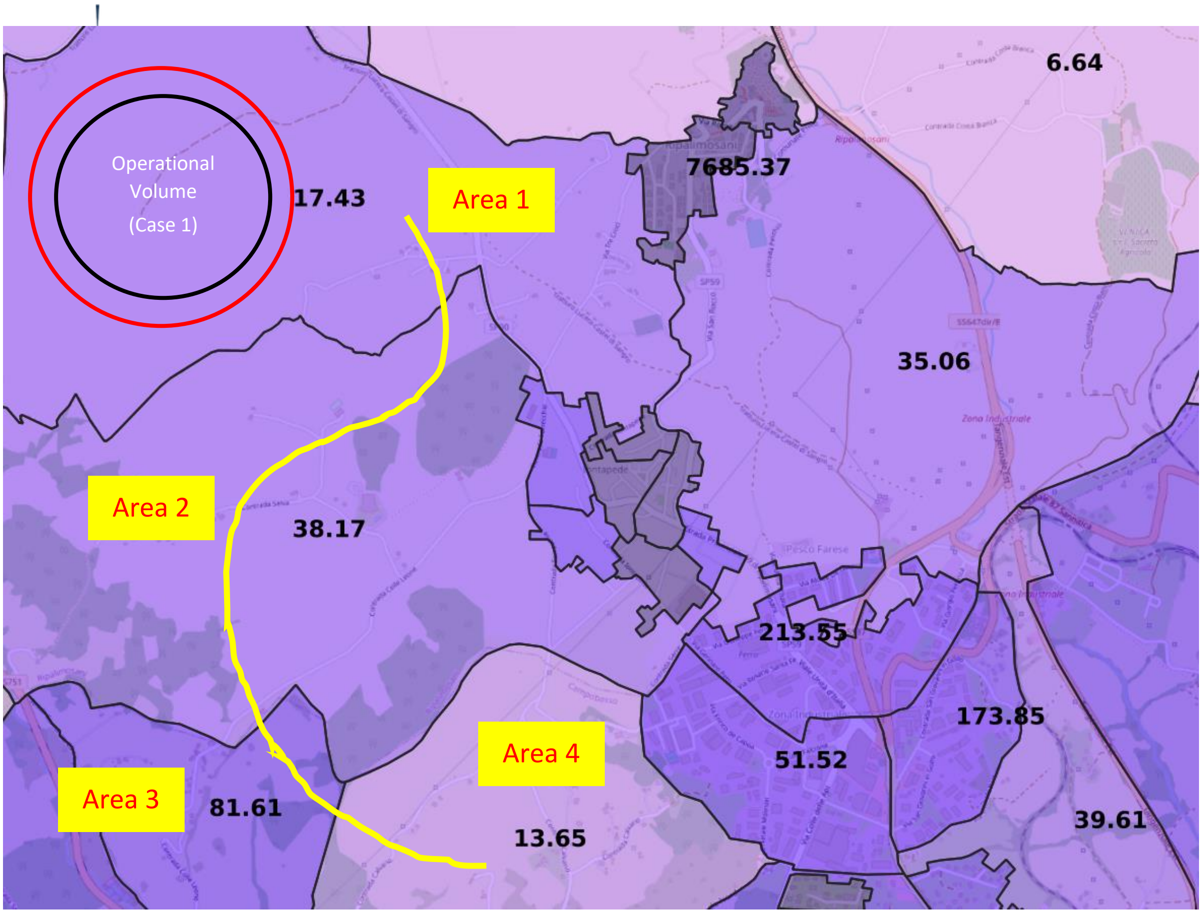

Figure 8: Population density map

For case 2, the most conservative approach would be to select the highest population density among the overflown areas. This approach would also allow the maximum operational flexibility without violating any assumption of the risk analysis.
However, if the planned time spent over the higher population density is significantly lower compared to the overall flight time, this may lead to overestimate the risk for people on the ground.
For example, let us consider the yellow flight trajectory represented in Figure 8. In this case the conservative approach would be to select the highest population density, i.e. 81.61 ppl/km2 from Area 3. However the planned time spent over this area is limited compared to the overall flight time. Therefore the OPU may want to select a lower population density, i.e. 38.17 ppl/km2 from Area 2. Selecting a lower population density would not underestimate the risk if the planned time spent over Area 3 is sufficiently low, but this would limit the operational flexibility and the OPU would need to guarantee that the planned flight trajectory remains unchanged. The following formula can be used, assuming that the TLS is expressed in number of fatalities per flight hour.

$$t_{max} \leq \frac{PD \times 60}{PD_{max}} \quad (35)$$

Where:

- t_{max} is the maximum time expressed in minutes that can be spent over the area with the highest population density, if this is not selected as the reference value
- PD_{max} is the population density of the area with the highest value
- PD is the population density the OPU would like to select for the ground risk assessment

In the above example if the time needed to overfly area 3 is less than 28 minutes, the population density of Area 2 can be selected as reference without affecting the overall target level of safety. However, it must be noted that if the higher density areas are those where critical phases of the flight take place (e.g. take-off and landing) the above approach may lead to an underestimation of the risk and the actual population density should thus be selected.

D.1.3 Data sources for population density

The primary data source for population density should come for census data. However, there are a variety of methods used to build population density maps starting from these data. In assessing suitability of the map used, the following general rules may assist, as proposed by [RD1]:

- Higher resolution maps are preferred to minimize the homogeneous assumption effects.
- Maps using census and ancillary data with more recent epochs are preferred.
- Preference should be given to maps produced by organisations providing detail on the methodology used for their map production, in addition to detail on validation efforts on accuracy.

When quantitative data for population density are not available the OPU unit should use their sound judgment to estimate the actual overflow populations density. As proposed by SORA Annex F, the following mapping between qualitative and quantitative measures could be adopted:

- If the operational volume and the buffer contain no people except those involved in the operation (e.g. pilot, payload operator, other military staff), the population density can be considered to be less than 1 people per square kilometre
- If the operation takes place over a rural area the population density could be considered less than 300 people per square kilometre. The actual value can be determined by considering the presence of building, public roads or other areas open to public access.
- If the operation takes place over a populated area the population density can be assumed to be between 3.300 and 15.000 people per square kilometre.

To support the above evaluation the OPU can make use of satellite images or on-site inspections.

D.1.4 Temporal variations of population density

Population density may vary over time in relation to daytimes and seasons. For this reason there are studies (e.g. [RD2]) suggesting the use of mobile phone data to have a better representations of population density over time. This information may be used to better reflect population density in different seasons, days of the week and even times of the day. In the future mobile data may be even used to provide real-time information on the population density of a given area.

It must be noted that mobile phone data, despite being available in principle, may be difficult to access in practice. Therefore Operational Units should always complement the information from static population density maps with additional analysis to confirm the correctness of the information used. This is particularly relevant for areas for which the population density estimated through census data is very low, but where the actual density may be significantly higher in practice. This is the case of shorelines in summer or ski resorts in winter.

D.2 Shelter factor

The quantitative model proposed by MUSRA for the computation of the shelter factor relies on the availability of several parameters. The capacity of a UA to penetrate a building/structure when crashing (*Protection_Factor*) and the lethality it causes when hitting a person (*Fatality_Factor*) are usually not available for commercial UAS but they can be modelled using the equation proposed by MUSRA. However, the factors related to the presence of people in each area and the percentage of them that are protected inside buildings are always difficult to be estimated. These numbers may have in fact a significant variability over time that makes difficult to estimate them in a consistent manner.

The Factor representing the percentage of the population that is protected inside buildings during the UAS flight needs therefore to be estimated in qualitative way considering the local conditions at the time of the flight. This factor should always be set to zero (leading to an overall shelter factor of zero) unless there are evidence that at least part of the people in the overflown or adjacent area are protected inside buildings. The supporting evidence may be based on:

- On-site inspections and appraisals
- Agreements with local authorities that may issue notices to remain inside buildings
- Considerations about daylight, season, temperature, office hours or other factors affecting the presence of people outside

In order to avoid overestimating the effect of people that are protected inside buildings, the overall shelter factor should always be proportionate to the actual reduction of people at risk on the ground. For example, if the population density of the overflown area is estimated to be of 100 ppl/km^2 and the number of people inside buildings is estimated to be 10, the overall shelter factor should not exceed 0.1.

D.3 Payloads

The carriage of dangerous payloads may affect the evaluation of the ground risk. MUSRA model explicitly considers the carriage of explosives as a worsening factor for the ground risk but the carriage of other types of dangerous goods can be handled by MUSRA as well. However, they are not considered as a worsening factor in the estimation of the risk but rather as a source of additional requirements for the operator to make sure they are handled correctly.

The reference for the definition of the abovementioned requirements is the ICAO Advisory Circular (AC) 102-37 **Errore. L'origine riferimento non è stata trovata.**. This AC classifies the dangerous goods in 9 different classes in accordance with the United Nations Recommendations Transport of Dangerous Goods. In addition it requires the operator to develop and implement Dangerous Goods Standard Operating Procedures including as a minimum:

- a training program that ensures that individuals handling dangerous goods are competent to perform the function;
- instructions for communicating information to relevant persons related to the dangerous goods being transported in case of an accident or incident;
- action to be taken in the event of emergencies involving dangerous goods; and
- instructions for the collection of safety data related to dangerous goods accidents and dangerous goods incidents.

With reference to MUSRA, the suggested process is to first check if the payload can be classified as dangerous and then implement the additional requirements as suggested by **Errore. L'origine riferimento non è stata trovata.**. These requirements have been already included in the MUSRA Operational Questionnaire.

D.4 Operations involving more UAS in the same volume

As explained in A.7, a collision between two UAS with no people on board will only cause fatalities if people on the ground would be hit by the falling debris created by the collision. For this reason, operating more than one UAS at the same time in the same airspace is considered a worsening factor only for the Ground Risk.

Assuming that a collision between two UASs will always cause the crash of the two aircraft, the probability of having a MAC between two UASs is equal to the probability of having a catastrophic failure on each of the UAS involved, as follows:

$$P_{cat\_ground} = P_{MAC\_UAS} \qquad (36)$$

This value of P_{cat_ground} needs to be compared with the one obtained by assessing the characteristics of the ground area. The value obtained here must be lower or equal, otherwise the risk for people on the ground will be higher than what is needed to meet the TLS. If this is not the case, the probability of having a MAC between two UA must be mitigated.

D.4.1 Initial P_{MAC_UAS}

The initial probability of having a MAC between two UAS depends on several factors, namely:

- The dimensions of the operational volume
- The number of UAS operated simultaneously
- The dimensions and relative velocity of the UA

Assuming that drones are following independent trajectories with no coordination and that they are not equipped with any DAA system, following the analysis carried out in **Errore. L'origine riferimento non è stata trovata.**, we can treat this problem as drones were molecules in a gas. According to this module the average distance a UAS can travel before having a collision, assuming that all UAS in the volume are moving at the same speed, can be computed as:

$$\lambda = \frac{0.75}{2\pi d^2 N} \qquad (37)$$

Where:

- d is the typical dimension of the UAS involved in the collision [m]
- N is the number of UAS in the airspace per unit volume [1/m^3]

The unmitigated probability of having a MAC between UAS in a given airspace can thus be computed by considering how much distance each UAS flying at a speed of v will travel in a given amount of time as follows:

$$P_{MAC\_UAS} = \frac{2\pi d^2 n v}{0{,}75 A H} \cdot 3600 \qquad (38)$$

Where:

- d is the typical dimension of the UAS involved in the collision [m]
- n is the number of UAS in the airspace [a-dimensional]
- v is the average speed of the UAS in the considered airspace [m/s]
- A is the ground area of the airspace considered [m^2] and H the altitude interval where the flights take place [m]
- P_{MAC_UAS} is the probability of having a Mid-Air-Collision per Flight Hour

For example if we consider a swarm of 10 UAS with a dimension of 0.3m flying over a 1km^2 area between ground and 100 m AGL and flying at 10m/s, the unmitigated probability of having a MAC can be found to be 2.7*10^{-3}/FH.

D.4.2 Mitigated P_{MAC_UAS}

The probability of having a MAC between UA can be reduced by implementing appropriate mitigations. Identifying the quantitative reduction of the collision probability thanks to the mitigations is not trivial. Therefore this guidance proposes to use a qualitative approach. Two cases are considered:

1. If the different UAS are under the responsibility of the same operator it is possible to assume that their flight is coordinated in such a way that the UAS are never put on a collision course unless there is a failure leading to a loss of control. Therefore it is possible to assume that in this case P_{MAC_UAS} is the highest value between the one computed from equation (2) and the highest probability of having a catastrophic failure of any of the UAS involved in the operation. This is a conservative assumption that does not consider the capability of the UAS that are still fully operational to avoid the one that is out of control.
2. If the different UAS are NOT under the responsibility of the same operator, external services (e.g. U-space) and/or a Detect and Avoid capability are needed to mitigate the risk of a MAC. In both cases the effectiveness of the mitigations will need to be assessed quantitatively considering their reliability and how much the probability of having a MAC is reduced thanks to their availability. For example if we assume to have a DAA on board with a Risk Ratio for MAC of 0.9, the mitigated P_{MAC_UAS} will be reduced of 10 times compared to the unmitigated value.