MoC on M2 medium robustness
UAS TeB Airworthiness TF
Presentation to Industry 22.02.2023
Introduction to the UAS TeB

→ A UAS TeB on the Open and Specific Categories of operations has been constituted Q4 2022

→ The TeB has defined several Task Forces
  → Adaptation of UAS regulation and AMC
  → LUC
  → Air Risk
  → Crew Training
  → AW
    → EASA, AESA, Austro Control, DAC Luxembourg, DGAC, ENAC, FOCA, HCAA, Irish Aviation Authority, LBA, CAA Latvia, CAA Norway, CAA Romania, CAA Netherlands

→ TFs report to TeB
→ The AW TFs has defined initial set of topics to tackle
→ Tracking by means of Task Sheets drafted and approved within the TF
AW TF initial topics

→ MoC for medium robustness mitigation means linked to design (“SORA M2”) – “D1” (subject of this workshop)
→ Published for consultation on 14.02.2023
  → Workshop on Medium Robustness - M2 MoC - Hybrid event (partially online and partially on-site) | EASA (europa.eu)
→ 3 weeks consultation (could be slightly extended if needed)
→ Comments to be provided through EASA CRT

→ Methodology to re-assess the critical area for the selection of the UA dimension (“D2”)

→ Review of proposed EASA MoC to Light UAS 2510 equipment, systems and installations

→ Identification of harmonized means of compliance for UAS operated in SAIL III
Structure of the M2 MoC

→ Explanatory Note
  → Background, actors, structure, plan, AW TF composition, acronyms, definitions

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→ MoC Body
Explanatory Note

Several communities addressed:

- Operators who are not designers of the UAS or of the mitigation means -> apply to NAA for OA (designers still support the application providing the evidence)
- Operators who have also designed the UAS and/or the mitigation means -> may apply to NAA for OA or to EASA for DVR
- Designers who have designed the UAS and/or the mitigation means and do not operate the UAS -> apply to EASA for DVR

Plan:

- Public consultation (ongoing)
- Workshop offered to Industry (Feb 22) for direct discussion before providing written comments
- After comments disposal, the document is planned to be adopted:
  - As GM to AMC to article 11 (Annex B), to support for M2 approval in OA frame
  - As MoC to Light UAS 2512, to support EASA DVRs
  - Basic content and concepts will be the same
- MoC is harmonized among European authorities and state-of-the-art: recommended to be immediately utilized for applications to NAAs (OA) and EASA (DVR)
Explanatory Note: important messages

→ The evidence defined by the document (chapter 2 or 3) should be delivered with the application. A list of supplementary evidence, when available, may be submitted to the authority.

→ The inherent attributes of the UA defining the GRC are not part of an M2 mitigation. A more accurate modelling of the inherent critical area is part of step#2.
  → M2 mitigation should be a clearly identifiable system, function or peculiar design elements (like frangible structures).

→ Operational limitations of flight speed or altitude, alone, cannot be used for GRC reduction in either step#2 or step#3.

→ The MoC is toward the current AMC (SORA 2.0). It adopts quantitative definitions based on lessons learned from SORA 2.5 to better clarify a “significant reduction of risk”
  → The MoC may be adapted after SORA 2.5 adoption.
Deliverable D2 mentioned in the EN

→ The SORA ground risk table may lead sometimes to an excessive estimation of the UA critical area leading to excessive GRC assignment

→ D2 will provide guidance to correct such excessive estimations and select the correct column in the ground risk table of step#2

→ Lighter than air out of scope

→ May lead to availability of a tool / engine, for industry and authorities, to numerically assess the critical area

→ Open points: how precisely to capture outcome under AMC to article 11
MoC on M2 medium robustness
Chapter 1 nominal target

→ As per SORA, robustness (L, M, H) is made up by integrity (safety gain) and assurance (method of proof)
→ Definition of integrity target as per EASA AMC (SORA 2.0): effects of impact dynamics and post impact hazards are significantly reduced although it can be assumed that a fatality may still occur
→ In order to clarify the “significant reduction” chapter 1 utilizes the lesson learned of SORA 2.5: risk to population reduced of approximately 1 order of magnitude (90%)
→ It is acceptable to only approximately reach the nominal integrity target, and partially qualitative assurance is acceptable for medium robustness

→ 3 types of M2 are defined:
  → Type 1: based on the claim of reduction of critical area
  → Type 2: based on the claim of reduction of lethality
  → Type 3: based on a mix of both

→ Chapter 1 clarifies the integrity definition for each type
Critical area: the sum of all areas on the ground where a person standing is expected to be impacted by the UA system during or after a loss of control event.
Type 1 nominal integrity target

1. Determine the correct column in SORA step#2

<table>
<thead>
<tr>
<th>Intrinsic UAS ground risk class</th>
<th>Max UAS characteristics dimension</th>
<th>Typical kinetic energy expected</th>
<th>Operational scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 m / approx. 3 ft</td>
<td>&lt; 700 J (approx. 529 lb)</td>
<td>VLOS/BVLOS over a controlled ground area¹</td>
</tr>
<tr>
<td></td>
<td>3 m / approx. 10 ft</td>
<td>&lt; 34 kJ (approx. 25 000 lb)</td>
<td>VLOS over a sparsely populated area</td>
</tr>
<tr>
<td></td>
<td>8 m / approx. 25 ft</td>
<td>&lt; 1 084 kJ (approx. 800 000 lb)</td>
<td>BVLOS over a sparsely populated area</td>
</tr>
<tr>
<td></td>
<td>&gt;8 m / approx. 25 ft</td>
<td>&gt; 1 084 kJ (approx. 800 000 lb)</td>
<td>VLOS over a populated area</td>
</tr>
</tbody>
</table>

2. Use the table below to find the nominal critical area (CAn) that should be associated with that column

<table>
<thead>
<tr>
<th>Max characteristic dimension (m)</th>
<th>≤1</th>
<th>≤3</th>
<th>≤8</th>
<th>≤20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal critical areas (m²)</td>
<td>0.8</td>
<td>8</td>
<td>135</td>
<td>1350</td>
</tr>
</tbody>
</table>

3. To achieve a 90% reduction the **claimed critical area (CAc)** must be shown to be equal to or less than that of the nominal critical area of the adjacent column to the left of the CAn.
Type 2: Lethality

- Nominal target: Lethality ≤ 0.1

- Lethality defined as probability of causing a fatal injury (fatality) if a person is hit within the critical area
Type 3: mixed

→ Nominal target: Lethality * CAc/CAn ≤ 0.1
  → E.g. if lethality would be claimed and demonstrated as 0.4 or less, then claiming and demonstrating CAc/CAn < 0.25 (claimed critical area 4 times smaller than the nominal one) would ensure the nominal integrity target is reached

→ However the above formula is not fully correct when CAn = 135 sqm, because the column on the left (1 m drone) is associated to a critical area (8 sqm) which is not 10 times less than the one associated to the 3 m drone
  → A correction factor is needed for the portion of reduction associated with the critical area
  → Nominal target: Lethality * [(0.9*CAc/127) + 0.043] ≤ 0.1  (linear correction)
Chapter 2. General Means of Compliance Core Principles

→ M2 medium has many different possible implementations and is highly dependend on the utilized drone.

→ It is the drones designers / equipment manufacturers duty, to implement test, and document a design.
   → They are liable for the correctness of the evidence.
   → The NAA/EASA will ensure, that the requirements are understood by applicants.
   → Evidence will support this assessment.

→ Chapter 2 contains all that is needed to be able to comply with M2.

→ As long as an applicant is able to provide evidence to all requirements of the SORA (AMC1 to Article 11 EU-2019/947), the compliance may be declared.
Chapter 2. General Means of Compliance

→ For each technical requirement, individual evidence should be available.

→ “Effects of impact dynamics and post impact hazards are significantly reduced although it can be assumed that a fatality may still occur.”

→ “When applicable, in case of malfunctions, failures or any combinations thereof that may lead to a crash, the UAS contains all the elements required for the activation of the mitigation.”

→ “When applicable, any failure or malfunction of the proposed mitigation itself (e.g. inadvertent activation) does not adversely affect the safety of the operation.”

→ MoC provides information for the necessary interpretation of these requirements
Chapter 2 – Documentation of the Mitigation

→ A technical description document should include:
  → the physical elements of the mitigation means.
  → the functional architecture of the mitigation means.
  → the installation of the mitigation means on the UAS.

→ An manual supplement document should include:
  → operational procedures for the utilization and maintenance of the mitigation means.
  → recommended training and instructions for the personnel responsible for these tasks.
  → training syllabus supplement for the operation of the mitigation means should be available.
Chapter 2 – Method of Impact Effect Reduction

→ Type 1 means: demonstrate by analysis or test that the expected critical area after the application of the mitigation means is lower than the nominal critical area of the next lower GRC.

→ Type 2 means: Demonstration of sufficient impact severity reduction could be achieved showing a 90% lethality reduction. Multiple options available.

→ Type 3 means: Combination of Type 1 and 2

→ The chosen method needs to be clearly identified in a report!
→ The expected/claimed reduced impact effect needs be calculated and the calculation needs to be added to the report.
Chapter 2 – Proof of Impact Effect Reduction

→ At least one representative flight test should provide the evidence of the claimed impact characteristics after activation.
  → descent speed, descent angle,
  → evidence of parts detachment,
  → impulse, transfer energy (where applicable).

→ Demonstration by simulation should be limited to cases in which testing would be highly impracticable.
  → Every simulation model should be validated by means of representative tests.

→ Test report should describe the conditions in which the tests took place and the outcome of each test. A summary of results should be provided.

→ In summary the test report is required to show, how the claimed reduction is being achieved and how this can be supported by test evidence.
Chapter 2 – Analysis of drone malfunctions

→ List all probable malfunctions that may cause the crash of the UA.
→ Justify how the mitigation means can be successfully activated in all of these situations.
   → That means, show how the means would work in each of the above.

→ But how?

→ SAIL I and II: design and installation appraisal
→ SAIL III and higher: safety assessment on the mitigation means should be a part of the overall system safety assessment (OSO #05, OSO 10/12).
Chapter 2 – Activation Reliability Testing

→ Demonstrate 30 successful activations of the means:
  → component testing,
  → flight testing or,
  → documented operational experience.

→ At least 1 successful activation shown in flight
  → Exceptions to the rule at the discretion of the authority

→ The test report should describe the conditions in which the tests took place and the outcome of each test. A summary of results should be provided.
Chapter 2 – Inadvertent activation

→ Inadvertent activation of the mitigation must not negatively affect the expected loss of control rate for an operation.

→ SAIL I operation:
  → no further evidence being required

→ SAIL II operations:
  → inadvertent activations should not be experienced in the testing of the system
  → A test report is considered to be sufficient evidence.

→ SAIL III and higher:
  → inadvertent activations need to be considered as part of the system safety assessment as required by OSO#05.
Chapter 2 – Negative safety impact

→ A failure or malfunction of the mitigation should not adversely increase the loss of control rate.
→ Includes intended or unintended behaviour of the mitigation means.
→ Not inadvertent activation

→ A mitigation means should not create additional danger for the people on the ground or other airspace users in case of a malfunction.
Chapter 3. Compliance examples

→ Chapter 2. is all that is needed to propose to a National Aviation Authority NAA or EASA a M2 mitigation solution.

→ However, it is understood that many applicants do not have the technical expertise or access to the UAS/Mitigation designs necessary to use Chapter 2.

→ Therefore, a set of examples meant to cover a large set of common mitigation means was drafted to ease the applications for less technical applicants.

→ Three of the examples are Parachute Recovery Systems

→ Fourth example is in essence a mass limitation / kinetic energy limitation on the drone being used.

→ Industry could propose based on Chapter 2. other examples to be added to the MoC / AMC. Previously suggested additional examples: autorotation, frangible wings (run out of time to add)
Example 1. sUAS parachute - (ASTM standard)

→ It was agreed in the Airworthiness TF that the ASTM parachute standard F3322-18 is certainly enough to comply to a Medium robustness M2 mitigation.

→ Since the standard has been in the market for a while and multiple parachute products are on the market tested to this standards, it was seen important for continuity to provide a smooth path for such devices to be acceptable also in the future.

→ However ASTM standard is missing a descent rate limitation and a wind speed limitation which were added based on available scientific literature for UAS impacts.
Example 1. sUAS parachute - (ASTM standard)

- UAS/Mitigation manufacturers must provide customers a set of documents that can then be delivered to NAAs with an application:
  - Description of UAS+PRS with operational limitations (descent speed, wind limit, minimum deployment altitude)
  - Installation and maintenance instructions
  - Description of training given to the remote crew – (this training could be also defined by the designer)

- Manufacturers must give to customers the TPTA test report if a NAA requests to see it from the UAS operator
Example 2. sUAS parachute

→ Essentially similar operational limitations and evidence required to be produced as with the ASTM parachute example.

→ However, different test set requirement to the ASTM standard.

→ 30 activation tests. One of which at least needs to be in flight to test the descent speed and minimum deployment altitude.
Example 3. Parachute for large UAS

→ Limited to UAS larger than the 3m size category.
→ Similar testing requirements to the Example 2 PRS, but the mitigation type is focused only on showing a reduced critical area.
→ Showing the reduced critical area requires setting an operational limitation on wind conditions below 12 m/s and showing a descent rate of equal or less than 8 m/s.
→ 30 activation test. One of which at least in flight showing the minimum deployment altitude and descent rate.
Example 4. sUAS impact kinetic energy reduction

→ This example allows an easy bridge from existing Open category C0 and C1 UAS mass limits as a M2 Medium robustness mitigation. Any UAS with C0 or C1 marking can get a M2 Medium without further evidence.

→ Other UAS can show with a drop test or a conservative terminal velocity calculation that they meet the reduced kinetic energy limitation.

→ Manufacturers simply need to be willing to conduct one drop test. Falling UAS can of course be captured by a net.