EASA
European Union Aviation Safety Agency

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

→ MoC Body

Table of contents

EASA

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

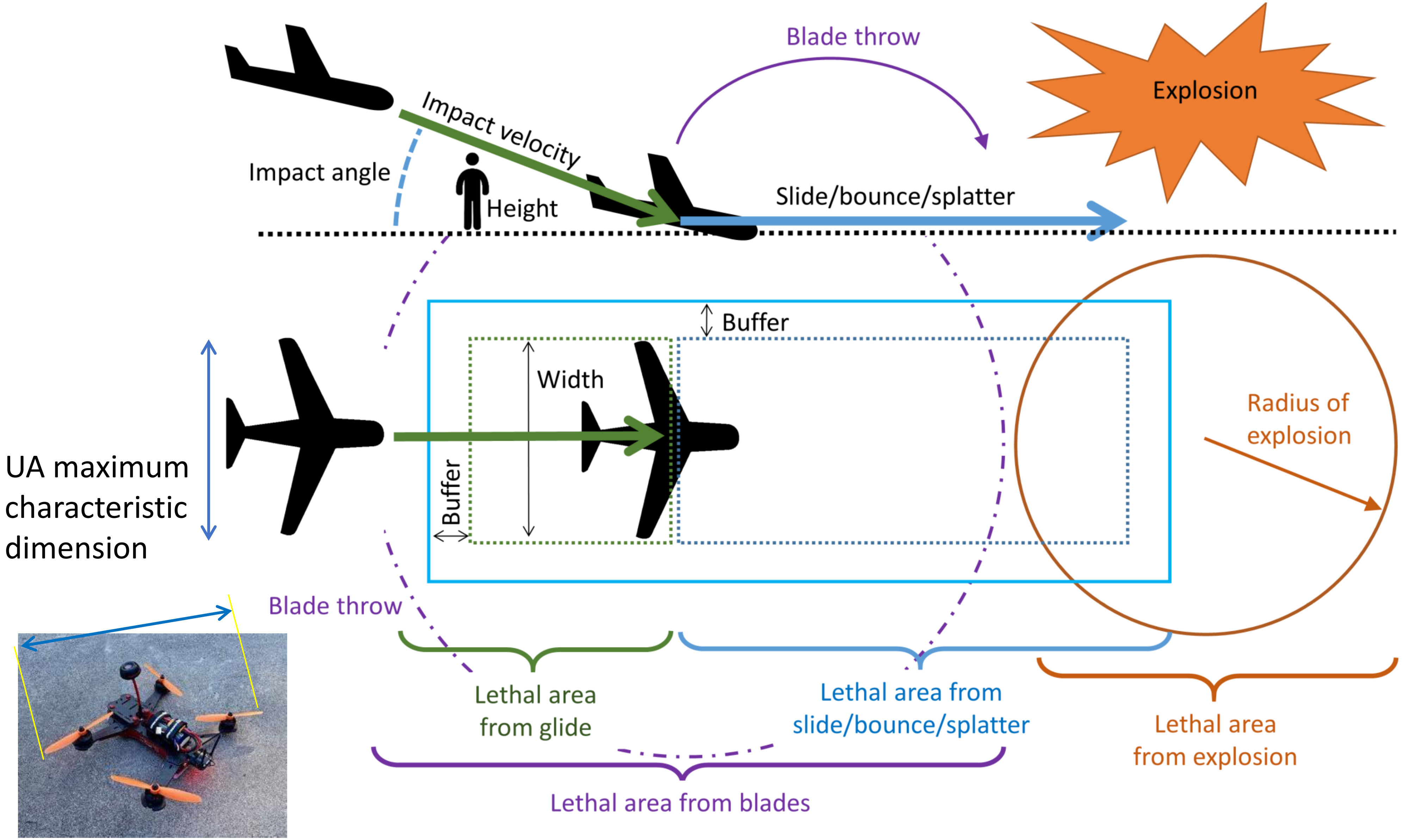
Chapter 1 nominal target

- 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

Type 1: critical area



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

Intrinsic UAS ground risk class				
Max UAS characteristics dimension	1 m / approx. 3 ft	3 m / approx. 10 ft	8 m / approx. 25 ft	>8 m / approx. 25 ft
Typical kinetic energy expected	< 700 J (approx. 529 ft lb)	< 34 kJ (approx. 25 000 ft lb)	< 1 084 kJ (approx. 800 000 ft lb)	> 1 084 kJ (approx. 800 000 ft lb)
Operational scenarios				
VLOS/BVLOS over a controlled ground area[3]	1	2	3	4
VLOS over a sparsely populated area	2	3	4	5
BVLOS over a sparsely populated area	3	4	5	6
VLOS over a populated area	4	5	6	8
BVLOS over a populated area	5	6	8	10
VLOS over an assembly of people	7			
BVLOS over an assembly of people	8			

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

Max characteristic dimension (m)		≤1	≤3	≤8	≤20
Nominal critical areas (m^2)	0.8	8	135	1350	13500

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

EASA

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 succesful 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.

EASA

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.