European Union Aviation Safety Agency	**SAIL III Means of Compliance with OSO#24** **"environmental conditions"**	Doc. No. **:** MOC OSO #24-01 Issue : 1 Date : 18 December 2023 Proposed ☒ Final ☐

SUBJECT	**UAS designed and qualified for adverse environmental conditions.**
REQUIREMENTS incl. Amdt.	Annex E of AMC 1 to Article 11 of Regulation 2019/947
ASSOCIATED IM/MoC	**Y**es☐ / No ☒
ADVISORY MATERIAL	**N**/A

List of acronyms

AEH	airborne electronic hardware
ASTM	American Society for Testing and Materials
AW TF	airworthiness task force of the UAS Technical Body
DAL	design assurance level
DVR	design verification report
GRC	ground risk class
GRr	ground risk reduction
LoC	loss of control
MoC	means of compliance
OA	Operational Authorization
RTCA	Radio Technical Commission for Aeronautics
SAIL	specific assurance and integrity level
SW	software
TPTA	Third Party Testing Agency

Reference documents

- EASA Guidelines for Design Verification Issue 3
- EASA AMC 20-136A
- EASA AMC 20-158A
- EASA MOC 2510-01

- RTCA DO-160G Environmental Conditions and Test Procedures for Airborne Equipment.
- ASTM F3367−21 "Standard Practice for Simplified Methods for Addressing High-Intensity Radiated Fields (HIRF) and Indirect Effects of Lightning on Aircraft"
- ASTM F3005 – 22 "Standard Specification for Batteries for Use in Small Unmanned Aircraft Systems (sUAS)"
- ASTM F3298-19 "Standard Specification for Design, Construction, and Verification of Lightweight Unmanned Aircraft Systems"
- ASTM F3478-20 "Standard Practice for Development of a Durability and Reliability Flight Demonstration Program for Low-Risk Unmanned Aircraft Systems (UAS) under FAA Oversight"

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1. Clarification on OSO #24 approach to compliance

OSO#24 requires that a UAS is designed and qualified in order to be able to cope with adverse environmental conditions.

For SAIL III it is classified as 'M' (medium) robustness and the following is requested:

"The UAS is designed to limit the effect of environmental conditions".

Consequently, the applicant should demonstrate that UAS functions, systems, equipment and items whose failure could directly result in the loss of control of operation are designed such that malfunctions due to environmental conditions are not probable. It is acceptable that malfunctions due to environmental conditions might happen during the lifetime of the UAS.

The applicant should demonstrate to have supporting evidence of the above, and such supporting evidence could be typically testing, analysis, simulations, inspection, design review, operational experience, ground testing, flight testing or combination thereof.

Applicants should define the envelope of the environmental conditions that they expect during operations. This definition includes relevant conditions for the operation, e.g. in particular temperature range, pressure-altitude humidity, vibration, exposure to water (incl. precipitation like rain, hail, snow) and other particles (sand, salt, …), exposure to High Intensity Radiated Fields (both radiated/conducted susceptibility should be taken into account), icing or other harmful environmental conditions.

When procedures and suitable detection means are put in place to detect adverse conditions and to avoid them reliably, this is sufficient to demonstrate compliance to this OSO with regard to such conditions.

HIRF Environment covers a wide variety of frequencies spread over the EM spectrum from 10 KHz to 40 GHz due to emissions of EM energy radiated by emitters such as radio, television, radar emitters, and other sources. It is understood that the exposition to such a wide variety of EM radiations with the appropriate intensity and waveform is not attainable by means of a flight test campaign.
Subsequently the applicant will have to select his approach among the following ones:

- Demonstrate the compliance vs. DO-160G section 20 (both conducted and radiated susceptibility) selecting the test levels reported in the attached environmental qualification form document[1]
- Imposing appropriate limitations, to be reported in the UFM, aimed to prevent flight whenever the flight geography includes any source of High Intensity Radiated Fields

[1] Provided herein as example; The declarations of compliance against each MoC shall be provided by means of appropriate forms that will be made available by EASA at a later stage.

Qualification for lightning in SAIL III is intended to be unnecessary for the majority of the products and operations. However in specific cases the product could be targeted to operations particularly exposed to lightning. Manufacturers may therefore address lightning in one of the following way:

1. Indicating that the product is not qualified for operations routinely exposed to unusual lightning risk; in this case lightning does not need to be addressed
2. Indicating that the product is qualified for lightning, specifying the applicable limits in the documents issued with the declaration and demonstrating such qualification by means of the applicable standards

Operating limitations should be established to ensure continued compliance with OSO#24. Typically, these may include provisions to prohibit flight into known adverse weather conditions, procedures and technical means to prevent inadvertent flight into adverse weather and for immediately exiting those conditions. Limitations and associated procedures should be established in the UAS Flight Manual.

Once the envelope of environmental conditions is defined, applicants should describe their approach to compliance with the following options:

- Laboratory tests in accordance with DO-160G; where applicable standards such as ASTM F3367−21 "Standard Practice for Simplified Methods for Addressing High-Intensity Radiated Fields (HIRF) and Indirect Effects of Lightning on Aircraft" and ASTM F3005 – 22 "Standard Specification for Batteries for Use in Small Unmanned Aircraft Systems (sUAS)" should be considered
- Flight test in accordance with ASTM F3478-20 and/or ASTM F3298-19
- Ground Testing (e.g. for rain, humidity, temperature, …) , as long as the applicant considers under their responsibility that ground tests are relevant to provide evidence of equipment withstanding certain environmental conditions.

  Ground tests may not always be appropriate to substitute flight tests, particularly in the following cases:

  1. if the impact on flight performance is required, or
  2. if flight conditions may significantly influence the outcome of the test
- A combination of the above

2. Laboratory testing approach

When DO-160G is selected, applicants need to assess the design of the UAS and define, for each system/equipment which may contribute to a LoC, the applicable environmental conditions to be tested and the associated test levels (minimum test levels are indicated in the environmental qualification form in Annex I provided as an example) based on the foreseen operational environment/associated limitations.

At completion of laboratory testing activity the applicant will have to fill an environmental qualification form for each system tested in accordance with the attached document template.

The applicant may choose to test to higher levels to substantiate extended resilience for specific environmental conditions.

A test report document should summarize the systems/equipment tested and the associated test levels.

3. Flight Test based approach

To demonstrate compliance by flight tests, the applicant should prepare a flight test programme that can confirm an adequate resilience of the UAS vs. specified environmental conditions, based on the foreseen operational environment.
The stepwise extension of the environmental envelope through an iterative form of testing is acceptable. In practice, the additional flight data gathered during operation can be used to amend the initial compliance demonstration and declaration. To comply with this approach, the test documentation needs to be complemented each time a limit is expanded, as to not lose the original set of data.

Additionally, information about the update of flight condition limitations need to be established systematically by means of a new formal application for a declaration with updated environmental limitations and revisions to the flight manual as well as any other relevant document, as applicable (e.g. maintenance instructions, pilot training syllabus, etc.).

Relevant data to substantiate the overall duration and environmental conditions encountered during the operations should be collected, analysed and recorded by the manufacturer if they want to use such operational data for credit.

The applicant can select one of the following methods described below:

1. Perform a complete flight test demonstration for all environmental conditions with a minimum duration of 40 flight hours in accordance with ASTM F3298-19 § 15.2.2.3 (4)

2. Perform an environmental flight test programme with a minimum duration of 3 flight hours spread over at least 3 flights for each environmental condition to be verified in accordance with ASTM F3478-20 Annex A1.

During the flight tests continuous exposure to the environmental condition taken into account needs to be achieved.
Irrespectively of the selected compliance approach, the applicant can combine some environmental conditions demonstration, if suitable. When environmental conditions are combined this needs to be

identified in the flight test results document. This report should provide evidence that even with the combined flight tests all the environmental conditions and their combinations are covered.
The entire flight test activity should be conducted on a set of UAS s/n to be specified by the applicant. Adverse effects/failures experienced on each s/n during the flight test campaign should be recorded by the applicant, collected in the flight test results document and assessed in order to determine the applicable environmental limitations.

The entire flight test activity will need to be conducted on a set of s/n to be declared by the applicant. Adverse effects/failures occurred on each s/n experienced during the flight test campaign should be recorded by the applicant, collected in the flight test results document and used in order to determine the applicable environmental limitations.

Applicants should consider the following specific sections of of ASTM-3298-19.

- 7.9.5.3 (3) for batteries
- 16.7.2.1 for design practices aimed to substantiate HIRF resilience
- A2.4.5 for icing conditions

To demonstrate adequate robustness regarding vibrations, the UA should be equipped with accelerometers installed on critical[2] equipment, recording the level of vibrations in all applicable flight maneuvers and checking that such level is compliant with the system installation requirements.

Where substantial operational experience is available, it can be used to claim compliance with environmental conditions, as applicable depending on the envelope of the operational experience and the configuration of the operated UAS wrt the UAS object of the SAIL III application.

4. Conclusions

Upon successful completion of the compliance demonstration tests and analysis of results, the applicant may declare under their responsibility that the UAS is designed to limit the effect of environmental conditions. Complementary to the declaration, compliance evidence should include, as a minimum a document describing the environmental limitations expected for UAS operation and the associated operating procedures (as per UAS Flight Manual) and supporting evidence for the claims of compliance (i.e. Environmental Qualification Forms, laboratory and /or flight test reports).

[2] Critical, within this MoC, should be understood as potentially leading to loss of control of the UA if that equipment is subject to failure

5. Compliance example

For a UAS operated:

- in temperature and humidity ranges that critical equipment evidently withstand according to available equipment information
- in no rain, hail and icing condition and no exposure to salt or other particles
- in absence of HIRF sources within the flight geography

The applicant may comply with this MoC establishing the limitations above and checking that the vibration levels during operation can be withstood. To this aim, the applicant may for example carry out 3 flights with the same S/N exposing the UA to the typical operational vibration pattern.

Annex I: environmental qualification form

Conditions	Applicable Standard	Test Procedure reference	Description	Qualification Level	Minimum DO-160G Acceptable Qualification Level	Qualification Evidence	Remarks
Temperature and Altitude	(i.e. DO-160G)	4.5.1	Temperature:		B2	Doc. XXX/ZZZ Ed. rev.	
Ground Survival Low Temperature					-15 °C		
Ground Survival High Temperature					+60 °C		
Operating High Temperature					+60 °C		
In-Flight Loss of Cooling					X		
Altitude					A1		
Decompression					X		
Overpressure					X		
Temperature Variation					B		

Humidity					A		
Operational Shocks and Crash Safety					X		
Vibration					S		
Explosion Proofness					X		
Waterproofness					Y (For systems exposed to environmental agents cat. W)		
Fluids Susceptibility					X		
Sand and Dust					D		
Fungus Resistance					X		
Salt Spray					X (For systems exposed to environmental agents cat. T)		
Magnetic Effect					Z		
Power Input					B		
Voltage Spike					A		
Audio Frequency Conducted Susceptibility - Power Inputs					B		
Induced Signal Susceptibility					ZC		
Radio Frequency Susceptibility (Radiated and Conducted)					TT		
Emission of Radio Frequency Energy					P		
Lightning Induced Transient Susceptibility					X		

Lightning Direct Effects					X		
Icing					X		
Electrostatic Discharge					X		
Fire, Flammability					X		

(X = declared as not tested as consdiered not necessary under applicant's responsibility on the basis of the guidance provided by MoC to OSO#24)