UNMANNED AIRCRAFT SYSTEMS RISK ASSESSMENT – A NEW APPROACH

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EXTENDED ABSTRACT

This research brings to public a thorough, yet innovative, methodology for the assessment of risk in the operation of Unmanned Aircraft Systems (UAS) with the goal of assisting the decision-making process of airworthiness authorities in the issue of permits to fly. It builds on the framework used for the assessment of risk in the operation of UAS developed within the European Defence Agency, called the Risk Assessment Tool. The limitations of the original framework were assessed, which led to a refinement of the requirements related to the design and integrity of the UAS and correspondent means of compliance, as well as to an implementation of the framework on a computational tool. The results of the proposed framework were obtained from the answers of specialists from six European military airworthiness authorities to a study case based on an UAS manufactured in Portugal.

Airworthiness certification is carried to assure an acceptable level of safety of an aircraft. While, for manned aircraft such safety levels are commonly accepted, for their unmanned counterparts there is still not a consensus, namely for smaller size UAS. Furthermore, the airworthiness certification process for small UAS is considerably demanding which, in turn, poses limitations to the operation that would push the development time and prices to an unpracticable value.

Along with the aforementioned, the intention of the development of dual use—civil and military—UAS has made it common to underapply existing standardization agreements (STANAG) that were specifically developed to define the airworthiness requirements of UAS, viz. STANAG 4702 [1], 4703 [2], and 4761 [3], due to the incremental focus on the cost reduction in the manufacturing of UAS. As a result, risk-

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based assessment methodologies have been developed to circumvent the limitations of the certification process and to assure an equivalent level of safety is achieved in UAS operations. In particular, the current most commonly accepted risk assessment frameworks are: a) the Guidelines on Specific Operations Risk Assessment (SORA), developed by the Joint Authorities for Rulemaking on Unmanned Systems (JARUS) [4]; b) the FAA Order 8130.34D Risk Index [5] and c) the Risk Assessment Tool (RAT) developed within the European Defence Agency Remotely Piloted Aircraft Systems (RPAS) Airworthiness Regulatory Framework (ARF) Group.

While SORA focuses on the analysis of the concept of operations, along with the ground and air risk classes and their respect specific assurance of integrity levels, it does not address an equivalent level of safety of the UAS regarding its probability of catastrophic failure; conversely the FAA Order 8130.34D Risk Index aims at identifying the required certification tasks as function of risk assessment, based on the flight area, safety checklist and risk category. Such methodology is used to support the issuance of the special airworthiness certificates or special flights permits for R&D, crew training, market survey and production flight testing purposes.

In contrast with the aforementioned methodologies, the RAT framework assesses the risk using a design integrity checklist which results in a score that is then converted to a probability of catastrophic failure and risk of hitting someone on the ground based on the population density. However, this methodology lacks on the assessment of operational and human factors. Figure 1 summarizes the level of assessment of each methodology in view of five factors – a score of 0 is not considered; a score of 3 is highly considered.

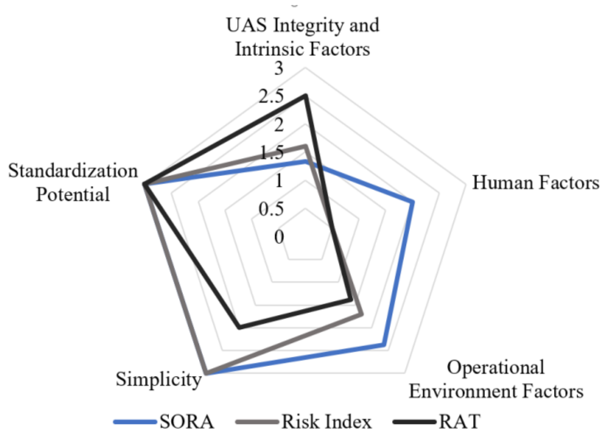

Figure 1 – Comparison of Risk Assessment methodologies with respect to different factors.

The RAT methodology is the basis of the present research. It is composed of three phases: I) determination of the integrity score—in a scale of [0;100]—through the answer of a 65 question Design Integrity Assessment Checklist (DIAC) that covers the eleven domains presented in Figure 2; II) application of correction factors to the score, in which safety aspects are assessed and if these are not present in the UAS a correction factor is applied to the score of the domain, cf. Figure 2; III) computation of the probability of failure (eq. 1) and respective risk of hitting someone on the ground in the event of catastrophic failure (eq. 5) based on the risk area of impact (A_{impact})—which is a function of kinetic energy (E) and maximum aircraft dimension (b), viz. span or rotor disk diameter—and population density ($Dens_{Pop}$) in the area of operation. The probability of killing someone given a hit is considered one ($Prob_{kill}$).

$$Prob_{CatastFailure} = 0.1\, e^{-0.069.Score} \quad (1)$$

$$Prob_{hit} = A_{impact} \times Dens_{Pop} \quad (2)$$

with $$A_{impact} = K \times b^2 \quad (3)$$

and $$K = \min[50; 17.5\ \times E + 3.2858] \quad (4)$$

which results $$Risk = Prob_{CatastFailre} \times Prob_{hit} \times Prob_{kill} \quad (5)$$

Domains	1. Organization	2. Adopted Design Standards	3. Tested Usage Spectrum	4. Stability, Control and Emergency	5. Ground Control Station	6. Structural integrity	7. Propulsion Integrity and	8. System Integrity	9. Safety Demonstration	10. Software Integrity	11. Continued Airworthiness
Maximum Score per Domain	9	2	10	18	3	6	17	10	5	15	5
No Quality Assurance System	1	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.6
No Technical Occurrence Tracking	1	1	0.8	1	1	0.8	0.8	0.8	0.6	0.8	1
No Failsafe (functionalities)	1	1	1	1	1	1	1	1	0.8	1	1
Human Machine Interface not Considered	1	1	1	1	0.6	1	1	1	0.8	1	0.6
No evidence of structural Integrity	1	0.8	1	1	1	1	1	1	1	1	0.6
No evidence of Propulsion Integrity	1	0.8	1	1	1	1	1	1	1	1	0.6
Inadequate E3 implementation	1	0.8	0.8	0.8	1	1	0.8	0.8	1	1	0.8
No FTA	1	1	1	0.6	1	1	0.6	1	1	1	0.6
No Software Life Cycle Assurance	1	0.8	1	0.6	0.8	1	0.8	1	1	1	1
No DO Configuration Management	1	1	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1
No Instructions for Continuous Airworthiness.	1	1	1	0.6	0.6	0.6	0.8	0.6	0.8	0.8	1

Figure 2 – Correction factors for score value obtained in phase I.

Despite the potential of the RAT for UAS safety and integrity assessment, its objectiveness and clarity need improvements. In this regard, the present research focused on improving the RAT to fit the current limitations and test it among the EDA RPAS ARF Working Group. In particular, the following developments were introduced in the methodology: i) the requirements of the DIAC were clarified and separated into single unequivocal questions, currently totalizing 103; ii) MoC were created for each question; iii) UAS characteristics and concepts of operation were introduced in the DIAC; iv) the DIAC was implemented in open source software and the score is automatically computed. These developments were tested by a sample of six international military airworthiness authorities using a 35kg maximum take-off mass, 4.2m span UAS test case, with a baseline score of 60. A public version of the implemented DIAC is made available through: https://goo.gl/forms/2chbmQZX4CZhmTVu1.

The results indicate an improvement over the previous version of the RAT, namely on the objectiveness of the DIAC, ease of use, interpretation and repeatability of the results obtained. An average score of 55 was obtained among the six MAWA representatives. Furthermore, it was found that the previous version of the RAT was too penalizing for the considered UAS, which resulted in a DIAC score of 20, and estimation of mean time between failures (MTBF) of 40 flight hours, cf. Table 1.

Table 1 – Comparison of DIAC between previous and proposed RAT methodology.

	Domain	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	Total	MTBF [flight h]
Original DIAC	**Max**	9	2	10	18	3	6	17	10	5.0	15	5		
	Min	0	0	0	0	0	0	0	0	-146	-20	0		
	Baseline	**2.5**	**1.5**	**7**	**13**	**3**	**3.5**	**9.25**	**7.5**	**-40**	**10**	**3.1**	**20**	**40**
Proposed DIAC	**Max**	9	2	10	18	3	6	17	10	5.0	15	5		
	Min	0	0	0	0	-4	0	-1	0	-146	-15	-10		
	Baseline	**4.8**	**1.0**	**8.4**	**12.8**	**3**	**3.5**	**9**	**6.2**	**-2.6**	**11**	**3.4**	**60**	**625**

In addition, the current research pushed the application of the framework further to propose a reference model that aims at facilitating the interpretation of the required score of a UAS by a manufacturer or authority inspector, using the municipality population density of Portugal, using statistical demographic data , which is presented in Figure 3.

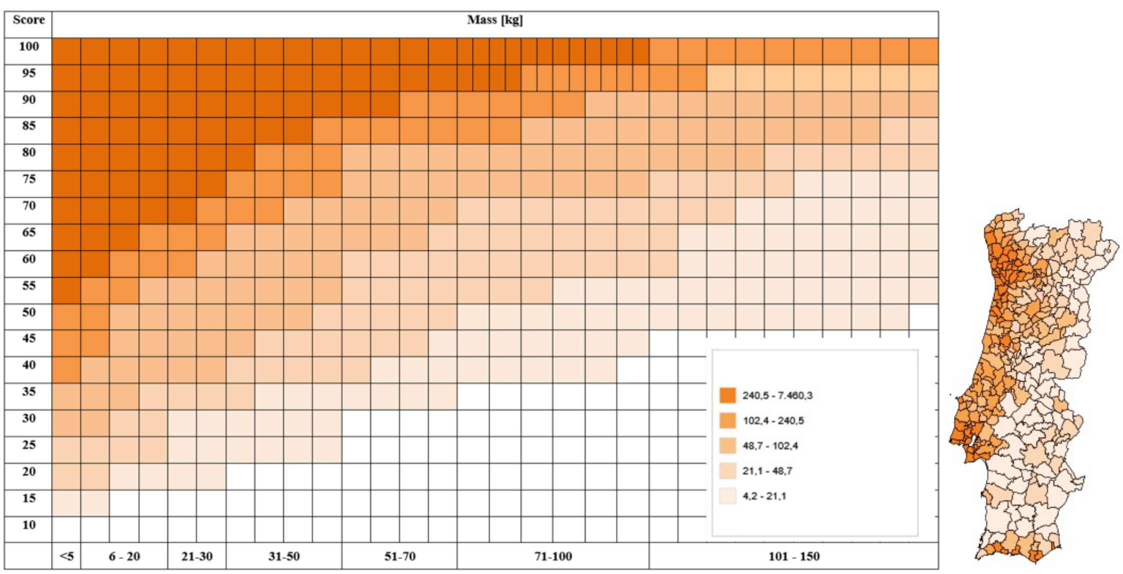

Figure 3 – Reference model for the score required to operate a UAS on a specific municipality in Portugal. Map adapted from [6].

References

[1] NATO, “STANAG 4702 Rotary Wing Unmanned Systems Airworthiness Requirements,” NSO, 2 ed, 2016.

[2] NATO, “STANAG 4703 Light Unmanned Aircraft Systems Airworthiness Requirements,” NSO, 2 ed., 2016.

[3] NATO, “STANAG 4671 Unmanned Aerial Vehicle Systems Airworthiness Requirements,” NSO, 2 ed., 2016.

[4] JARUS, “Guidelines on Specific Operations Risk Assessment,” JARUS, 2017.

[5] FAA, “Order 8130.34D Airworthiness Certification of Unmanned Aircraft Systems and Optionally Piloted Aircraft,” 2017.

[6] PorData, “Population Density of Portugal,” 2018. [Online]. Available: https://www.pordata.pt/Municipios/Densidade+populacional-452. [Accessed 02 05 2018].