UAS IN RESCUE AND CRISIS MANAGEMENT – DETERMINATION OF OPERATIONAL RISK

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Abstract

Unmanned aerial vehicle systems play an increasingly important role in crisis management and rescue. The specificity of such operations makes it difficult to conduct a typical risk analysis. The paper presents European and national regulations concerning the use of UAS in relation to operational safety issues. It presents also an outline of proposed changes in relation to safety issues in the Polish aviation law. Next it contains a discussion on the meaning of risk and provisions regarding how to perform operational risk assessment in EU regulations and provides a characterization of the specificity of UAS operations in rescue and crisis management. The general principles and the procedure of the SORA analysis method were presented. The SORA method was referred to rescue and crisis operations and an assessment was made of its usefulness. A proposal was made for an alternative ERA-2.0 risk analysis method and presented for UAS rescue and crisis management operations.

Keywords: safety, risk analysis, SORA, ERA-2.0, UAS, rescue, crisis management

1. INTRODUCTION

Many services play a role in crisis management and rescue: the State Fire Service (Feltynowski, 2022), the Police, the Border Guard, the Maritime Search and Rescue Service (Polish Journal of Laws/Dz.U. 2012 item 733), the GOPR (Mountain Volunteer Emergency Service), the WOPR (Water Volunteer Rescue Service) and sometimes also units of the Polish Army or of the Territorial Defense Forces. The main goal is to prevent, combat and eliminate the effects of a crisis. SAR (search and rescue) activities consist of finding people in danger, helping them and moving them to a safe place. Rescue operations can also be part of crisis management activities.

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For several years, UAS have been part of the permanent equipment used in rescue operations and anti-crisis activities (Polish Journal of Laws/Dz.U. from 2022 items 261, 583, 2185). A crisis has the following inherent features (in relation to people and property): a crisis is a sudden or growing event, threatening human life, health, property or the environment, and opposing it requires forces and resources exceeding local capabilities (Wikipedia: kryzys). Crisis management consists of four phases: prevention, preparation, response and recovery. There are also a number of types of rescue: medical, chemical, mining, mountain, water, air, sea rescue and others. UAS are an important element of service equipment that enables efficient and effective response in rescue and crisis situations. In all phases of crisis management, UAS can be successfully deployed in different ways. Similarly, in diverse types of rescue, UAS will contribute in dissimilar ways.

The effectiveness of the use of UAS and their equipment is not only determined by the pilots' skills, but a whole range of factors that should be taken into account when preparing for operation. Operational risk analysis in the use of UAS allows identifying sources of threats, defining threats, evaluating the risk and applying methods intended to reduce the level of risk. Operational risk analysis of UAS in rescue and crisis management (Borkowski, Lieb, Max, 2020) allows not only enhancing the effectiveness of operations, but also helps to save lives and property.

2. OPERATIONAL SAFETY – REGULATIONS

Many constitutive European and national regulations regarding the use of UAS refer to safety issues. The safety management systems contained therein, apart from generalities, should solve the problem of risk analysis and methods of risk reduction at a more detailed level. State security and public order protection authorities have internal regulations regarding the use of UAS. However, in such ordinances, organizational matters are usually in the foreground. Threat risk management in UAS operations leaves much to be desired. Regulations of various levels refer to the Aviation Law and/or to EU regulations (2019/945 and 2019/947).

Ordinance No. 63 of the Police Commander in Chief of 7 October 2019 on detailed rules for the use of unmanned aerial vehicles in the Police, the currently binding act, well illustrates the signalled problem. It takes into account the safety issues by imposing the following obligations:

"Article 2, item 3 – a police UAS pilot may be a police officer or police employee holding valid UAS pilot licenses in the "special" category in accordance with Commission Implementing Regulation EU 2019/947 of 24 May 2019.

Item 7 – a police UAS observer may be a policeman or a police employee holding a UAS pilot license, and during the performance of activities with the use of the police UAS, supporting the police UAS pilot, Article 8. Before the flight, the police UAS pilot checks the possibility of performing a police UAS flight, in particular:

- weather conditions;
- land relief;
- operating limitations of the police UAS;
- airspace availability".

It is significant that Ordinance No. 63 of the Police Commander-in-Chief does not refer to any national provisions. These are as follows:

- Guideline No. 7 of the President of the Civil Aviation Authority of June 9, 2021 on the methods of performing operations using unmanned aerial vehicle systems in connection with the entry into force of the provisions of Commission Implementing Regulation (EU) No. 2019/947 of May 24, 2019 on the rules and procedures for the operation of unmanned aerial vehicles;
- Guideline No. 24 of the President of the Civil Aviation Authority of 30 December 2020 on the determination of geographical zones for unmanned aircraft systems;
- Act of July 3, 2002 Aviation Law, Polish Journal Laws/Dz.U. of 2022, items 1235, 1715.

The above-mentioned regulations apply to the principles and conditions of safe UAS operations, both directly and indirectly. Guidelines No. 7 define the conditions for performing operations with the use of an unmanned aerial vehicle system in the "open" category and the "specific" category, including in clubs and associations of model aircraft – and other procedural requirements. The guidelines discuss procedures that allow operations to be carried out only by specified methods and have an estimated level of risk allowing safe flights (NSTS). Guidelines 24 indirectly address security issues.

3. AMENDMENT OF THE AVIATION LAW

Until 2021, UAS flights were excluded from the provisions on manned aviation in the Aviation Law and in the relevant regulations. At the beginning of 2021, EU Regulations 2019/945 and 2019/947 came into force. They significantly change the approach to UAS and safety issues, recognizing that unmanned flights are part of a joint aviation activity together with manned flights. In order to adapt the Polish aviation law to the EU set of laws, regulations in this area are subject to the process of amendment. The draft amendments to the Act of 3 July 2002 – the Aviation Law (Polish Journal of Laws/Dz.U. of 2020, item 1970, as amended), hereinafter referred to as the "Act - Aviation Law" and amendments to other acts as well as the issuance of relevant national regulations are intended to ensure the application of new European Union regulations concerning unmanned aircraft and unmanned aircraft systems. The most important change proposed in the draft is the introduction of a new section dedicated to unmanned aerial vehicles to Aviation

Law. The planned section VIa "Unmanned aerial vehicles" of the Act has been divided into 6 chapters, the most important of which are: performing operations with the use of unmanned aerial vehicle systems, geographical zones for unmanned aerial vehicle systems and the register of UAS operators. The draft assumes that the provisions governing the principles of performing operations using unmanned aerial vehicle systems for civil use will, in principle, also apply to operations by entities whose statutory task is to provide all kinds of services performed in the public interest (security and public order protection authorities). The justification for such a position of the legislator is that the principles of performing operations using UAS and the level of qualifications of persons performing them for state services should be the same as for all airspace users.

The issue of risk analysis and risk reduction is discussed as a reference to Article 11 of Regulation 2019/947. The draft indicates that the operational risk assessment referred to in Art. 11 of Regulation No. 2019/947/EU, is developed using the methodology specified in the guidelines of the President of the Office, published in the Official Journal of the Civil Aviation Authority. The draft Air Law enigmatically mentions the risk assessment in Art. 156c. ("The risk assessment referred to in Article 11 of Regulation 2019/947/EU is carried out using the UAS ICT system").

4. RISK IN EU REGULATIONS

A critical element of European UAS regulations is the level of risk of UAS operations. EU Regulations 2019/945 and 2019/947 divide VLOS and BVLOS flights and three categories of operations in terms of risk:

1. open – low risk;
2. specific – medium risk;
3. certified – high risk.

They also establish UAV classes C0 to C6. – as per Figure 1.

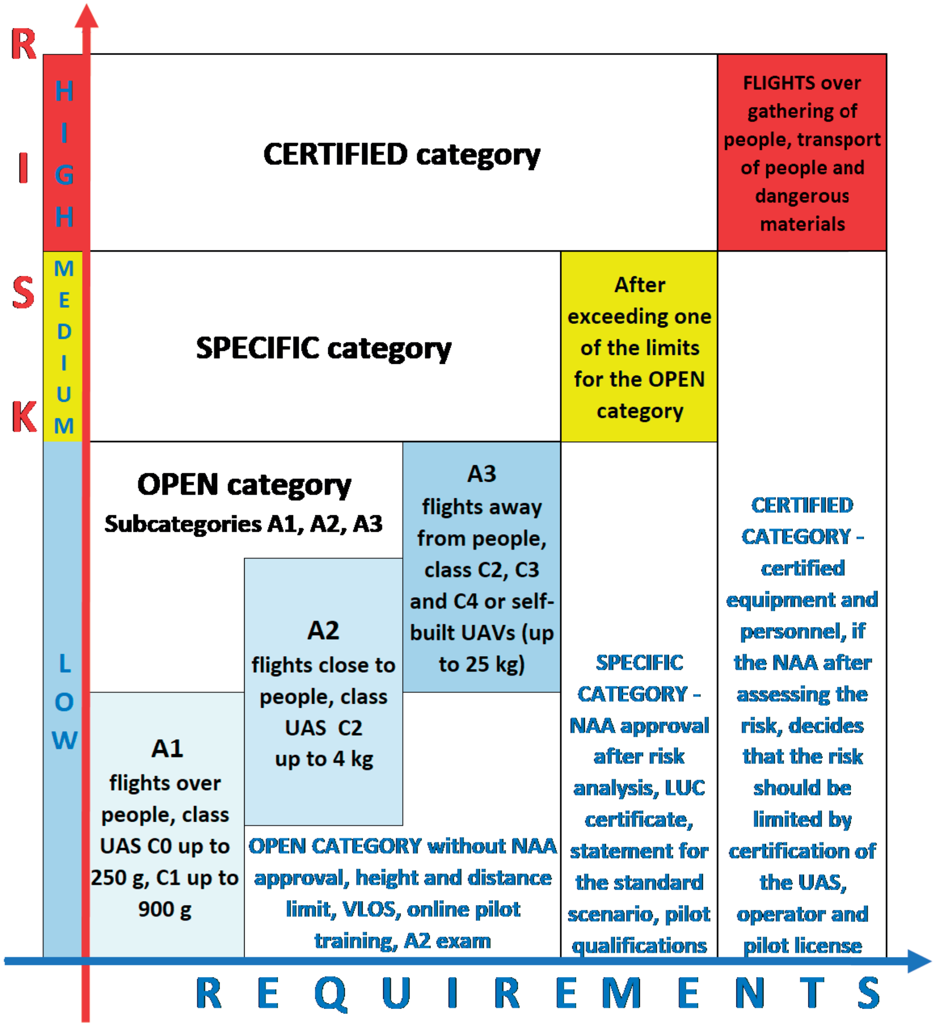

Figure 1. Division into categories of UAS operations

5. PROVISIONS REGARDING THE PERFORMANCE OF THE OPERATIONAL RISK ASSESSMENT

Article 11 of Regulation 2019/947 sets out provisions, i.e. the content, scope and requirements, for conducting an operational risk assessment. The basic condition of the risk analysis equalizes the level of safety of manned and unmanned operations – in item 3. "The assessment shall propose a target level of safety, which shall be equivalent to the safety level in manned aviation, in view of the specific characteristics of UAS operation".

Below is a summary of the content of Art. 11.

Item 1. The operational risk assessment describes, suggests and indicates:

- nature of the operation;
- operational safety objectives;
- risks on the ground and in the air, taking into account the following aspects:
  - degree of threat to third parties or property on the ground,
  - UAS complexity, performance and operational features,
  - probability of mid-air collision, class of airspace,
  - type, scale and complexity of the operation,
  - extent of third party awareness and control of threats;
- possible risk mitigation measures;
- level of robustness of the measures.

Item 2. The description of UAS operations must contain at least the following elements:

- nature of the activity;
- operational environment, population, orographic conditions, types and capacity of airspace, risk buffer;
- complexity of operations, personnel and technical resources required;
- UAS features and performance;
- personnel, competences, training.

Item 3. Already discussed in the first paragraph of this section of the paper.

Item 4. Risk indications include the identification of all of the following:

- On the ground:
  - VLOS/BVLOS,
  - population density of the overflown areas;
  - flying over an assembly of people;
  - dimension characteristics of the unmanned aircraft /MTOM (kinetic energy);
- In the air
  - airspace capacity and class;
  - impact on other air traffic, conditions:
    - altitude of the operation,
    - controlled versus uncontrolled airspace,
    - airport versus off-airport areas,
    - urban vs. rural areas,
    - separation from other traffic.

Item 5. When identifying possible risk mitigation measures necessary to achieve the assumed level of safety, the following solutions shall be taken into account:

- risk mitigation measures for persons on the ground
  - limitating the range of the geographical area,
  - limiting the length or distribution of a time slot;
- strategic risk mitigation measures (common rules, common airspace structure or common airspace services);
- capability of coping with possible adverse operational conditions;

- level of competence and expertise of staff;
- organization - operating procedures and maintenance procedures;
- risk of human error;
- structural features and performance of the UAS (availability of measures to mitigate the risk of collision, energy limitations or fragility, design in accordance with recognized standards and minimizing the effects of a possible failure).

Item 6. The robustness of the proposed risk mitigation measures shall be assessed to determine whether they are commensurate with the safety objectives and risks of the intended operation, in particular to ensure the safety of each phase of the operation.

The main provision of Article 11, which acts as a guiding principle for the construction of the other provisions is point 3. It introduces a fundamental condition that balances the level of safety between manned and unmanned operations. Due to the high safety level of manned of manned flights, this condition places great demands on the level of risk in unmanned flights. The remainder of Article 11 is aligned with the condition of equalizing the level of safety of manned and unmanned flights.

Item 1. Describes the general scope of the risk assessment, it is a kind of table of contents of the further part of Article 11.

Item 2. Applies to UAS operations (technique, people, organization). The scope of this point is very broad and requires compiling further information on the concept of operations within the conducted activity, operational environment, operator, details of the UAS used, personnel, their competences and training.

Item 4 and item 5 complement each other by dividing the procedure into two parts, the aim of which is to determine the risk on the ground and in the air (point 4) and specify the risk mitigation measures (point 5) necessary to achieve the assumed level of safety for both types of risk.

Item 6 imposes the need to determine whether the risk mitigation measures proposed in the analysis are commensurate with the safety and risk objectives. This point requires assessing the effectiveness and appropriateness of the means used in relation to the planned operation. It does not indicate any criteria for evaluating the means used, leaving only a subjective assessment of commensurability.

6. SPECIFICITY OF UAS OPERATIONS IN RESCUE AND CRISIS MANAGEMENT

UAS are a very helpful tool to be used in crisis management and rescue as part of ensuring the public safety of the state. The UAS operations performed are definitely different from other commercial or recreational applications.

UAS operations in crisis situations and rescue operations have their own specificity affecting safety, which consists of a number of factors. The most important ones include:

- Time deficit;
- Dynamics of changes in the situation;

- Unrecognized area;
- Unrecognized airspace;
- Ensuring safety (from chemical, biological, radiation, explosion hazards, etc.);
- Temperature, smoke;
- Difficult visibility/seeing (day/night, haze);
- No choice of weather conditions;
- High potential for signal/range interference;
- Unpredictable possibility of human presence;
- Terrorist threats.

With regard to crisis management, these factors are of greatest importance for the response phase. In the case of rescue operations, many of these factors may occur simultaneously.

The divergent nature of the operations has a significant impact on the human factor (HF). Operations with the use of UAS refer to situations in which the pilot works under the burden of responsibility (Marzec, Fellner, 2018) for the health and life of people and property of high value. If perceived stress turns into a negative phase (distress), unforced errors by the pilot, observers and those in charge of the operation may occur. Resistance to stress, difficult conditions, unfamiliar terrain, time deficit or other factors can have a huge impact on the efficiency of staff work and the level of safety of the operation.

7. UAS OPERATION RISK ANALYSIS METHOD

The Commission Implementing Regulation (EU) 2019/947 in Article 11 does not indicate a risk analysis method. EASA has accepted and recommends the methodology of the SORA analysis, although concurrently it states that other methods may be used and accepted by aviation authorities. The JARUS organization (Joint Authorities for Rulemaking on Unmanned Systems) brings together world experts from 61 countries, EASA and EUROCONTROL, representatives of national aviation authorities, industry and airlines. The document submitted by the JARUS organization under the name "SORA v2.0" (Specific Operations Risk Assessment) (JARUS, 2019) presents a model of UAS operation risk management to be used by operators and aviation authorities. The methodology presented in this document is intended to assess the risks associated with the operation of unmanned aerial vehicle systems (UAS) of any class and size and type of operation. JARUS states that SORA is suitable for, but not limited to, specific categories operations for which hazard and risk assessment is required. The specific objective of SORA is to propose a risk assessment methodology to support applications to the NAA for permission to conduct UAS operations and obtain approval for flights in a special category in accordance with the EU Commission Implementing Regulation 2019/947. SORA is also a tool for the appropriate aviation authority to determine whether an operation can be conducted safely and what measures should be taken

to reduce the risk to an acceptable level. SORA contains safety objectives that must be met with different levels of robustness commensurate with the risk. SORA is intended to replace the risk management methods used in manned aviation, which cannot be directly and effectively applied to unmanned aircraft flights.
In the SORA method, in ten consecutive steps, the applicant presents assumptions and determines the level of safety of UAS operations adequate to the accepted degree of risk. The ten steps of the procedure are presented in Figure 2.

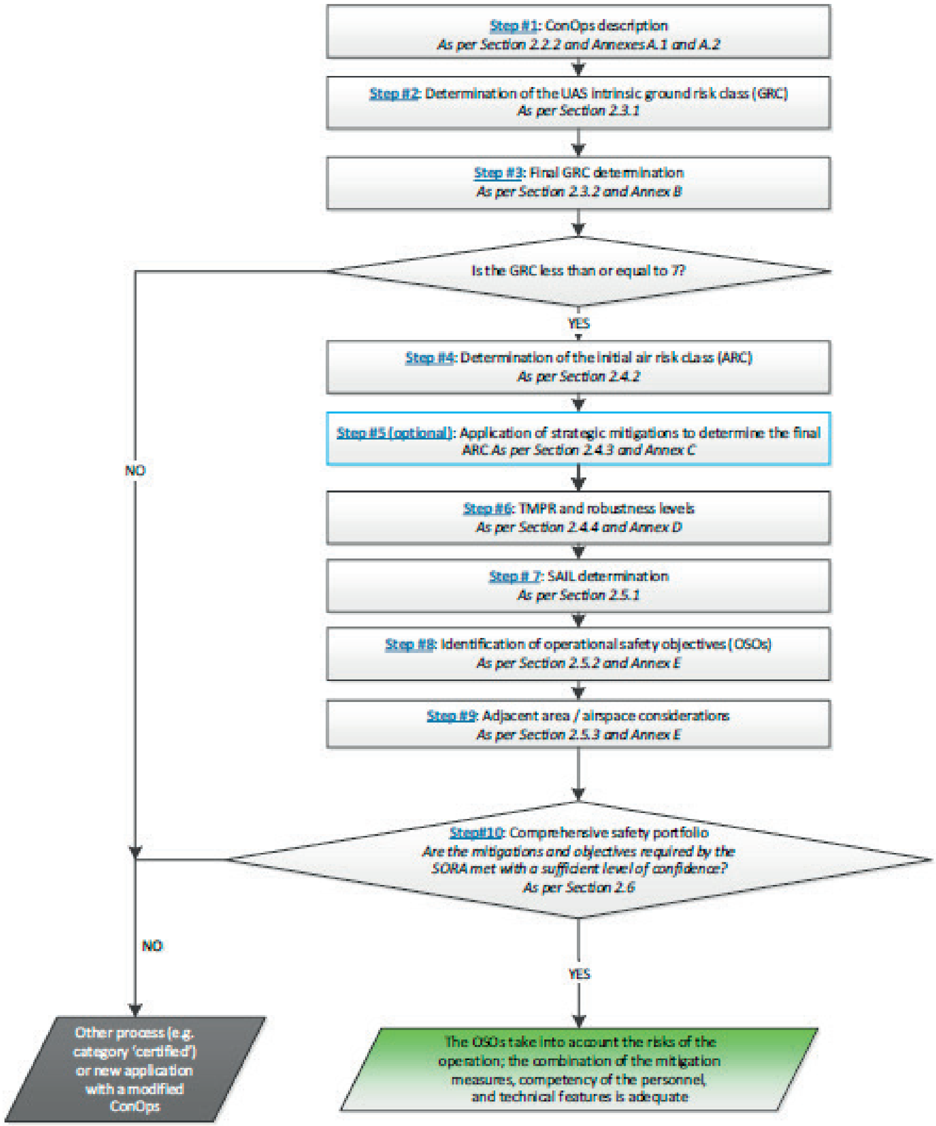

Figure 2. The SORA process
Source: (JARUS, 2019)

The damage categories in the SORA document are as follows:

- fatal injury to third parties on the ground;
- fatal injuries to third parties in the air;
- damage to critical infrastructure.

Each event results in several different categories of damage. The SORA document focuses on damage events (e.g. UAV disaster) that are short-lived and may result in loss of health or life. Events with secondary, long-term effects (e.g. toxic emissions over time) are excluded from this assessment. The document uses the concept of robustness (under Article 11 of Regulation 2019/947) – any objective of risk reduction or operational security can be demonstrated at different levels of robustness, which consists of two elements – integrity and certainty. Three levels of robustness are proposed by SORA: low, medium and high, commensurate with the risk. The determination of robustness is obtained by combining the level of integrity provided by each constraint with the level of assurance stating that the declared safety gain has been achieved.

The actions used to justify the level of integrity (safety gain) are detailed in Appendices B, C, D and E. These appendices contain guidelines or reference industry standards and practices, as appropriate. The level of assurance is considered to be:

- low, where the applicant simply declares that the required level of integrity has been achieved,
- medium, when the applicant provides evidence that the required level of integrity has been achieved (tests, experiments),
- high when a competent third party has recognized that the level of integrity has been achieved.

8. SORA ANALYSIS PROCEDURE

#1 step one contains a description of the operation concept (ConOps) – context. It requires the applicant to collect and provide relevant technical, operational and system information necessary to assess the risk associated with the planned UAS operation. Annex A of SORA covers the preparation of ConOps in detail.

#2 step two – determination of the intrinsic ground risk class GRC. The inherent GRC involves the risk of the UAV hitting a person (in the event of loss of control of the UAV, assuming a reasonable level of safety). The applicant reads the GRC value from Table 1 based on the UAS technical parameters and the scenario of the planned operation.

#3 step three – Final GRC determination, details in Annex B. Annex B lists the types of risk mitigation measures used:

- M1 – Strategic risk mitigation related to GR;
- M2 – Reducing the effects of hitting the ground;
- M3 – An effective ERP (Emergency Response Plan) implemented by the applicant in the event of loss of control over the UAV.

Integrity and assurance criteria levels for risk mitigation are included in Annex B.

Table 1. Determination of the intrinsic GRC

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[6]	1	2	3	4
VLOS in a sparsely populated environment	2	3	4	5
BVLOS in a sparsely populated environment	3	4	5	6
VLOS in a populated environment	4	5	6	8
BVLOS in a populated environment	TBD[7]	TBD[7]	TBD[7]	TBD[7]
VLOS over an assembly of people	7			
BVLOS over an assembly of people	TBD[7]			

Source: (JARUS, 2019)

#4 step four – determination of the initial air risk class – ARC (Air Risk Class). The ARC is a qualitative indicator of the possibility of an unmanned aircraft encountering a manned aircraft in a typical generalized civil airspace. ARC is the initial assignment of aggregated airspace collision risk, prior to the application of mitigation measures. ARC-a defines the airspace where the risk of a collision between a UAV and a manned aircraft is acceptable without adding any tactical constraint. ARC-b, ARC-c, ARC-d generally define an airspace with an increasing risk of collision between an UAV and a manned aircraft. The initial risk class in the air – ARC is determined from the diagram – Figure 3.

#5 step five – Application of Strategic Mitigations to determine Residual ARC (optional). Risk mitigation activities are conducted when it is recognized that the operating space may have a different collision risk than that assigned to the generalized initial ARC.

#6 step Six – Tactical Mitigation Performance Requirements TMPR and Robustness Levels - Appendix D. #6 allows you to determine the residual ARC. Within SORA, there are two classifications of tactical countermeasures, namely:

a) VLOS where the pilot and/or observer uses human vision to detect the aircraft and take action to maintain a safe distance from and avoid collision with other aircraft.

b) BVLOS where alternative methods to human perception, such as the use of devices or systems, allow maintaining a safe distance and avoiding collisions with other aircraft (e.g. ATC, TCAS, DAA, Flarm, U-space, etc.).

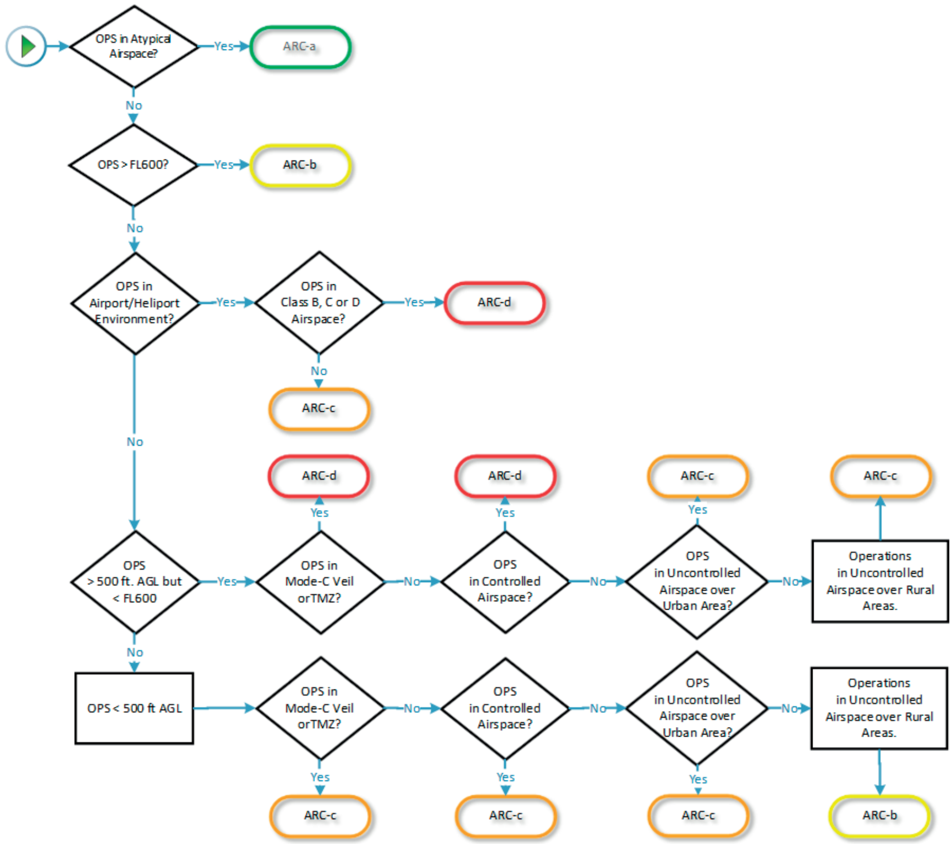

Figure 3. ARC assignment process

Source: (JARUS, 2019)

#7 step seven – defining SAIL (Specific Assurance and Integrity Levels). The SAIL parameter consolidates ground GRC and airborne ARC threat analyses. It is one table-based indicator that defines the level of SAIL risk assigned to a specific ConOps (operation).

#8 step eight – identification of operational safety objectives - OSO. SAIL indicates a specific level of risk and ways to reduce it for the analyzed operation. The OSO tables contain the associated level of robustness for a given SAIL value and the corresponding risk reduction requirements for all integrity and assurance criteria.

- Technical issues with UAS, OSO 1-10
- Deterioration of external systems supporting UAS operations, OSO 11-13
- Human error, OSO 14-20
- Unfavourable operating conditions, SPA 21-24

The requirements for achieving a safe level of risk corresponding to the designated robustness index contained in the OSO derive from compiled past experience of experts. Comparison of the activities assumed in ConOps with the requirements of OSO give an answer whether the operation can be identified as safe – details in Annex E.

#9 step nine – Adjacent Area/Airspace Consideration

#10 step ten – Comprehensive Safety Portfolio. In #10, the applicant prepares a safety portfolio of the SORA performed and presents to the NAA and the ANSP methods including risk mitigation and how safety objectives will be achieved. These include:

- Countermeasures for modifying the internal GRC
- Strategic Mitigation for Initial ARC
- Tactical Mitigations for Residual ARC
- Contiguous area/airspace considerations
- Achievement of operational safety objectives

Upon presentation of the safety portfolio, the NAA may or may not authorize the operation (discretionary).

9. SORA METHODOLOGY IN RESCUE AND CRISIS MANAGEMENT IN RELATION TO REGULATION 2019/947 (ARTICLE 11)

The analysis of the SORA methodology as a process of estimating the risk level of UAS operations shows that it was created for the purposes of Article 11 of Regulation 2019/947. SORA has indubitable advantages, which include:

- Compliance with the provisions of art. 11 of the Regulation (meeting the requirements for obtaining consent by the NAA);
- Clear separation of risks on the ground and in the air, together with methods their mitigation;
- Identification of operational security objectives (OSO) based on past experience;
- High level of versality of use.

SORA also has certain shortcomings. With regard to rescue and crisis management, a number of questions arise regarding the adaptation of SORA to this type of operation. The considerations presented in the previous chapters show that UAS operations in rescue and crisis management are characterized by a special specificity that does not fully comply with provisions of Article 11 of the Regulation or the SORA risk analysis methodology.

In the planned UAS operations, all the requirements contained in Article 11 of the Regulation should be considered and then referred to in the SORA methodology. Due to the differences between the features of operations in rescue and crisis management from other applications (commercial and others), it is not possible to consider all elements of Article 11 and further in the SORA methodology. Hence the question whether (or to what extent) it is possible to determine all the issues specified in Article 11 for rescue and crisis management operations and then analyze the risk in the SORA methodology.

To answer this question, the SORA methodology was referred to the requirements of Article 11 of Regulation 2019/947. The specificity of the considered UAS operations was taken into account. A summary has been prepared that indicates whether the mandatory elements of Article 11 of Regulation 2019/947 can be defined (or to what extent it is possible) in the SORA method for rescue operations and in crisis management activities. The assessment of whether the elements of Article 11 of the Regulation are identifiable relates to the specific features of these operations. Crisis management activities consist of four phases: prevention, preparation, response and recovery. Each has a different specificity. For this reason, each of them was evaluated separately. For factors that can be determined in accordance with the requirements of Art. 11, the value 1 was adopted, the lack of possibilities was marked with the value 0 – Table 2.

Table 2. Assessment of the usefulness of the SORA method in rescue and crisis management in relation to the provisions contained in Article 11 of Regulation 2019/947

PROVISIONS of ART. 11 of REGULATION 2019/947		RESCUE	CRISIS MANAGEMENT			
			prevention	preparation	response	elimination of effects
Item 2	**Description of operations using UAS**					
	nature of the activity	1	1	1	1	1
	operating environment, population, orographic conditions, types and capacity of airspace, risk buffer	0	1	1	0	1
	complexity of operations, personnel and technical resources required	0	1	1	1	1
	features and performance of the UAS	1	1	1	1	1
	personnel, competencies, training	1	1	1	1	1
Item 4	**Risk indications**					
	On the ground:					
	VLOS/BVLOS	0	1	1	1	1
	population	0	1	1	0	0
	assembly of people	0	1	1	0	1
	dimension characteristics /MTOM (kinetic energy)	1	1	1	1	1
	In the air:					
	airspace capacity and class	0	1	1	0	1
	impact on other air traffic, conditions	0	1	1	0	1
	altitude of the operation	1	1	1	1	1

PROVISIONS of ART. 11 of REGULATION 2019/947		RESCUE	CRISIS MANAGEMENT			
			prevention	preparation	response	elimination of effects
	controlled or uncontrolled airspace	0	1	1	1	1
	airport area or the area outside the airport	0	1	1	1	1
	urban vs. rural areas	0	1	1	0	1
	separation from other traffic	0	1	1	1	1
Item 5	**Risk indications include**					
	risk mitigation measures for persons on the ground:					
	limitation of the scope of the geographical area	0	1	1	0	0
	limiting the length or distribution of the time slot	0	1	1	0	1
	strategic risk mitigation measures (common rules, airspace structure or common airspace services	0	1	0	0	1
	capability to cope with possible adverse operational conditions;	0	1	0	0	1
	level of competence and expertise of staff	1	1	1	1	1
	organization - operating procedures and maintenance procedures	1	1	1	1	1
	risk of human error	0	1	1	0	1
	structural features and performance of the UAS	1	1	1	1	1
Item 6	the robustness of the proposed risk-mitigating measures shall be assessed in order to determine whether they are commensurate with the safety objectives and risk of the intended operation	0	1	1	0	1
	number of points obtained out of a possible 25	**8**	**25**	**23**	**13**	**23**
	Max. 25 points percentage	**32%**	**100%**	**92%**	**52%**	**92%**

The summary shows that it is possible to fulfil more or less a third of the elements described in Article 11 of the Regulation for rescue operations, about half of the elements for response activities in crisis management, and almost all elements for the other phases of crisis management. Therefore, for rescue operations and response (crisis management), there are no grounds for conducting a risk analysis using the SORA method, and the results obtained from incomplete information may prove to be unreliable.

10. ALTERNATIVE RISK ANALYSIS METHOD FOR UAS RESCUE AND CRISIS MANAGEMENT OPERATIONS – ERA-2.0

There are many methods of risk analysis used in aviation. With regard to operations with the use of UAS, they allow obtaining results to determine the level of risk, which enables its possible reduction. The SORA methodology created for UAS operations allows a fairly high accuracy of potential risk for standard operations. However, due to the specificity of unmanned operations performed in rescue and crisis management, not only SORA but also many analysis methods lose their usefulness or can be used with major limitations. The main features of rescue operations and crisis management, which make the use classical analytical methods difficult, include in the first place the lack of knowledge of a number of changing conditions encountered during and at the site of the operation. The time deficit is the second very important factor preventing the methodical preparation of the operation. In addition, flight decisions are made on an ongoing basis and may be subject to significant changes during the undertaken action. This is due to the unpredictability and dynamics of this type of operation.

Since the specificity of rescue operations and crisis management does not allow methodical preparations due to the lack of information and time, precise determination of the level of risk is practically unattainable. A partial solution is to use methods that will determine the level of risk for a given operation in real time (Ersin et al., 2017) and, if classified negatively, will enable its possible reduction. The features of such a method require the use of unambiguous, reliable data and a very short analysis time. The approximate result of the analysis can then be verified during the course of activities and making verification decisions.

According to the author, a method that enables an approximate risk assessment is ERA-2.0, a modified second stage of the proprietary ERA (Easy Risk Assessment) method (Wyszywacz, 2022). It takes into account the properties of actions that are known and its implementation takes a very short time. The application enables the determination of indicators defining the risk on the ground F (fall) and the risk in the air C (collision). The sum of the indicators, F+C combining both risks, indicates the level of risk tolerance for a given operation. To conduct the analysis, one must determine the fall index F (defining the ground risk) and the collision index C (defining the risk in the air) and select the appropriate item from the drop-down lists. The maximum flight altitude of 250 m AGL was assumed to quantify the level of the fall index F. Most UAV flights are performed in the VLOS category at altitudes up to 120 AGL. This limitation is included in the EU regulations applicable from January 1, 2021 regarding VLOS flights in the open category. Flights above 120 m AGL are performed much less frequently. The following criteria were also used:

- MTOM UAV up to 5 kg and up to 25 kg (the largest UAV dimension below 3 m)
- Categories of VLOS and BVLOS operations;

- The population density of the area over which flights are conducted.

The operational ground area is divided into:

- Controlled Ground Area;
- Sparsely populated ground area (up to 53 people/km^2 – rural areas in Poland and similarly in Europe);
- Populated area (up to 4000 people/km^2 – urban areas in Poland and similarly in Europe);
- An area with a high density of people (over 4000 people/km^2).

Flights above 150 m AGL entail a much higher probability of collision due to the greater possibility of meeting manned aircraft (higher airspace density index). The term instrumentation means equipping UAS with devices and the ability of using systems that reduce the risk of collisions in the air, such as e.g. DAA (Detect And Avoid), FLARM (combination of "flight" and "alarm") or ADSB (Automatic Dependent Surveillance-Broadcast) devices integrated with the system for coordinating unmanned aircraft flights with PansaUTM or ATC services. Flights in controlled airspace, in fixed or flexible structures above 150 m AGL, performed in accordance with the obtained conditions and permits, are also exposed to an increased probability of collision.

The summed value of the F and C indicators, for the conditions specified in the analysis, makes it possible to determine the total risk and determine its tolerance for the planned operation. The application interface is shown in Figure 4.

Using the application is easy and does not require any special knowledge or skills. The selected F and C indicators determine the level of risk on the ground and in the air, respectively. The sum of the indicator values (index^{FC}) determines the total risk for UAS operations. The higher the value of a given indicator, the higher the level of risk. The index^{FC} indicates the suggested risk tolerance in the application. By lowering a higher indicator (choosing from the list of parameters of operations with lower risk), the level of tolerance changes. The method allows quick recognition of the parameters that enable the adjustment of the risk to the appropriate level of its tolerance.

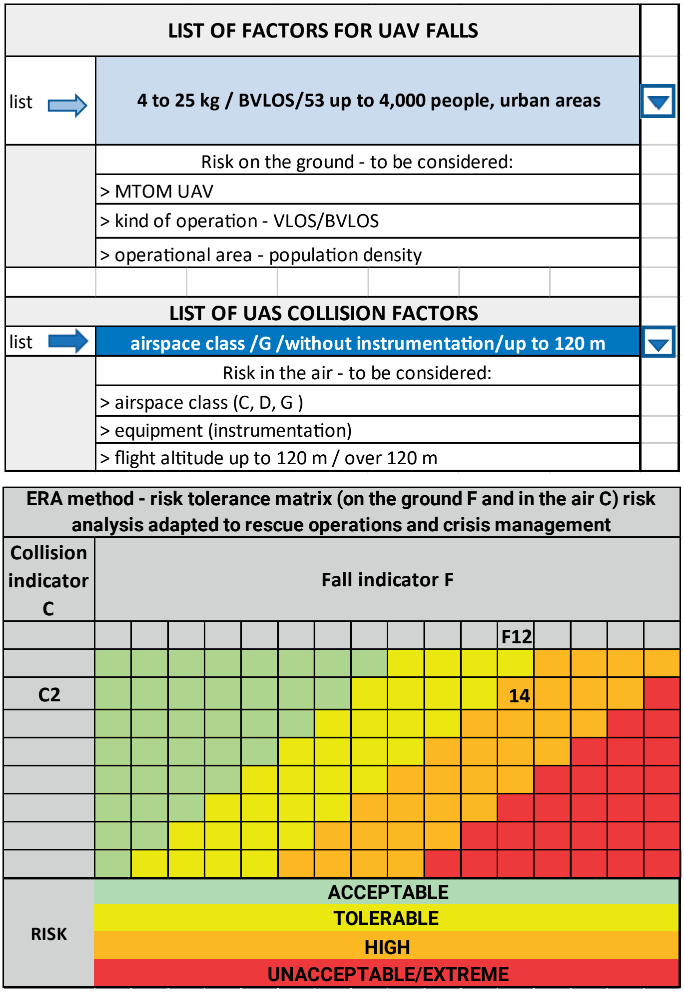

Figure 4. Illustration of the application used to determine the risk tolerance for UAS operations

11. SUMMARY AND CONCLUSIONS

Operational safety is a leading theme in almost all UAS flight regulations. However, European and national regulations do not prescribe methods of risk management and risk analysis for UAS operations. The provisions of the regulations require such risk reduction in UAS flights to equal the level of safety with manned flights. The Polish Aviation Law has not yet been amended in terms of operations performed by UAS and compliance with applicable EU regulations. Recommendations of the President of the Civil Aviation Authority, actions of the Polish Air Navigation Services Agency or ministerial orders are endeavouring to fill this gap in the regulations.

The existing regulatory practices practically bypass the issue of hazard risk management. They deal with the procedures allowing UAV flights for a predefined level of risk, excluding operations performed by uniformed services, for which the analysis and risk management is very difficult or impossible. It can be argued that UAS operators and pilots are unable to effectively optimize the level of risk in their rescue and crisis management operations. The use of risk analysis and reduction methods in this situation is based on the pilots' individual knowledge and experience. This proves the deficit of recommendations, procedures and methods that enable risk optimization and reduction or avoidance of damages and losses.

Article 11 of Regulation 2019/947 presented the elements to be taken into consideration in the field of risk analysis, which is the basis for issuing consent to operations in a special category. In response to the requirements imposed by the regulation, the SORA methodology was developed, which is recommended by EASA. The SORA methodology is a complex set of analytical activities that allows determining the level of risk and meets the requirements of Article 11 of the Regulation. The weakness of SORA is that the procedure is intended for standard operations in which all parameters are known and risk mitigation can be achieved by changing ConOps and using properly prepared strategic and tactical actions. The specificity of UAS operations in rescue and crisis management makes it impossible to use such a procedure due to the unpredictability of many elements. The analysis of the requirements contained in Article 11, compared with the SORA methodology in relation to rescue operations or in activities related to crisis management, showed its low usefulness.

The risk analysis method for the specific operations under consideration must be based on clearly defined parameters of operational activities and, at the same time, on the short time of the analysis. Naturally, the number of parameters considered will be much lower than in the SORA procedure, yet the final result will be immediate and useful. The use of the second part of the ERA-2.0 analysis was proposed and a customized application was presented, which is not time-consuming and at the same time quite simple and intuitive. The application, if approved, will be expanded and will become more accurate, taking into account a larger number of parameters while maintaining a very short execution time.

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LIST OF MAJOR ABBREVIATIONS AND ACRONYMS

ADS-B – Automatic Dependent Surveillance-Broadcast
AGL (Above Ground Level) – height above ground level;
ARC – initial air risk class (SORA method)
ATC – Air Traffic Control;
BVLOS (Beyond Visual Line of Sight Operation) – operations beyond the visual range of the pilot;

C0 to C6 – classes of UAS
CONOPS – the concept of operation
DAA (Detect and Avoid) –"see and avoid", the ability to see or detect threats and take appropriate action to meet acceptable flight rules;
EASA – European Union Aviation Safety Agency,
ERA (Easy Risk Assessment) – easy risk assessment, proprietary risk analysis method dedicated to UAS;
ERP – Emergency Response Plan (SORA method)
FLARM – (combination of "flight" and "alarm") – an electronic system used to selectively warn pilots of potential collisions between light aircraft,
GOPR – Górskie Ochotnicze pogotowie Ratunkowe (Mountain Volunteer Emergency Service)
HF – the human factor;
ICAO – International Civil Aviation Organization;
JARUS – Joint Authorities for Rulemaking on Unmanned Systems;
MTOM (Maximum Take-off Mass) – the maximum mass of the unmanned aircraft specified by the manufacturer or constructor, including payload and fuel, at which the unmanned aircraft can be operated
NAA – national aviation authority;
NSTS – national standard scenario
OSO – operational safety objectives (SORA method)
GRC – intrinsic ground risk class (SORA method)
Pilot – a pilot of an unmanned aircraft UAS - unmanned aerial vehicle system;
SAIL – Specific Assurance and Integrity Levels (cumulative risk of ARC and GRC in the SORA method)
SORA (Specific Operations Risk Assessment) – risk assessment for operations of a specific category;
UAS operator – any legal or natural person operating or intending to operate one or more UAS;
UAV – Unmanned Aerial Vehicle
VLOS (Visual Line of Sight Operation) – operations within the pilot's visual range; SBSP – system bezzałogowego statku powietrznego – UAS
WOPR – Wodne Ochotnicze Pogotowie Ratunkowe (Water Volunteer Rescue Service)

SBSP W RATOWNICTWIE I ZARZĄDZANIU KRYZYSOWYM – OKREŚLENIE RYZYKA OPERACYJNEGO

Abstrakt

Systemy bezzałogowych statków powietrznych odgrywają coraz większą rolę w zarządzaniu sytuacjami kryzysowymi i w ratownictwie. Specyfika takich operacji utrudnia przeprowadzenie typowej analizy ryzyka. W artykule wskazano regulacje europejskie i krajowe dotyczące użytkowania SBSP w odniesieniu do zagadnień bezpieczeństwa operacyjnego. Przedstawiono zarys projektu zmian w odniesieniu do zagadnień bezpieczeństwa w polskim prawie lotniczym. Następnie omówiono znaczenie ryzyka i przepisy dotyczące wykonania oceny ryzyka operacyjnego w regulacjach unijnych. Scharakteryzowano specyfikę operacji SBSP w ratownictwie i zarządzaniu kryzysowym. Przytoczono ogólne zasady koncepcji i procedurę metody analizy SORA. Odniesiono metodę SORA do operacji ratowniczych i działań kryzysowych oraz dokonano ocenę jej przydatności. Zaproponowano i przedstawiono alternatywną metodę analizy ryzyka ERA-2.0 dla operacji SBSP ratowniczych i zarzadzania kryzysowego.

Słowa kluczowe: bezpieczeństwo, analiza ryzyka, SORA, ERA-2.0, SBSP, ratownictwo, zarządzanie kryzysowe