Unmanned Aerial Vehicle in the Aviation System: An Overview of the Safety Risk Management Approaches

Lidija Tomić, Olja Čokorilo

University of Belgrade, Faculty of Transport and Traffic Engineering, Vojvode Stepe 305, 11000 Belgrade, Serbia

Abstract

The global transportation sector is faced with a great number of innovative solutions that are expected to make transportation more efficient, sustainable, and environmentally friendly. Such a solution is the Unmanned Aerial Vehicles (UAV) which are recognized as a leading innovation that simultaneously provides various business opportunities and luxury to humanity. However, this innovation brings high risk to the manned aviation industry, and also to third parties on the ground. As aviation is the most vulnerable industry, since UAVs and aircraft share the same airspace and therefore potentially catastrophic consequences if collisions occurred, it is important to learn how to manage those safety risks. The aim of this paper is to present an overview of the different approaches for safety risk management for threats that arise from UAVs operations in the aviation system, and to discuss included steps, methods, and associated challenges. Some of the methods are proposed through examples for which purpose they are adequate. The paper concludes by highlighting current advanced approaches in the analyzed field, developed by aviation regulatory organizations.

Keywords: Aviation safety, Risk management, UAV, Risk assessment, SORA, MEDUSA

1 Introduction

The UAV is on the way to changing the transportation industry as we know it. The increase in UAV use over the last few years, as well as a wide range of their applications, has led to the need to understand and manage safety risks emerging from UAV operations, especially in those environments in which drones may influence air traffic in progress [1].

Different involved entities (airlines, airports, air navigation service providers, civil aviation authorities, etc.) will have different perspectives and approaches for risk management related to UAVs as safety issues. Despite mentioned differences, there is a common generic process that should be followed. This process needs the application of appropriate safety methods/models.

Like the many developments in aviation are initiated as a direct result of aircraft accidents [2], the development of risk and safety methods/models dated from the beginning of the 1960’s. As a reaction to accidents, first causal methods/models are developed with the aim to find out their main causes in order to prevent further ones. At the same time, collision risk methods/models appeared with a proactive role in redesigning the air traffic system in order to safely accommodate increasing traffic demand. Since 1970’s, the aviation community becomes more concerned about the human role in accidents, resulting in the development of Human factor errors methods/models. Moreover, during the 1990’s public increased awareness of the severity of accidents in airports’ vicinity and their influence on surrounding inhabitants and the environment resulting in the development of Third-party risk methods/models [2]. In civil aviation, the modeling of safety risks is in most cases performed using one of the models/methods within these four accepted groups. Examples of some models/methods that should be appropriate for analyzing safety issues, from different perspectives, are presented in the paper. However, in order to respond to specific threats, such as UAVs, the entities involved tend to develop specific methods. In practice, this new method usually involves combining several...
common methods, or their basic principles, in order to adapt to the new system and its environment. Moreover, in order to respond as quickly as possible to exposed threats, and manage the risks arising from them, aviation organizations are entering into joint ventures (cooperation) which results in advanced, specially-designed risk management approaches.

Currently, two complementary methods for assessing risk from UAV operations developed by aviation organizations are Specific Operational Risk Assessment (SORA) and Methodology for the U-Space Safety Assessment (MEDUSA), both with the aim of enabling safe integration of UAVs in the airspace. The main principles of those two methods are presented in the paper as an example of good practice.

2 Safety Risk Management Approaches in Aviation

The risk management process is a main part of the Safety Management System (SMS). The SMS is based on systematic hazard identification and risk assessment in order to minimize negative consequences that may arise from the unsafe events (loss of human life, damage or destruction of property, and financial, environmental, and social costs). As safety is defined in relation to the risk, any safety consideration must include the risk concept. The risk management approaches can be roughly divided into two groups: traditional and modern/advanced approaches [3].

I. Traditional approach in the safety risk management

The traditional approach to aviation safety management involved monitoring of air traffic/aviation system, isolating adverse events, and implementing measures to prevent them from occurring. In practice, it means a reactive approach, i.e. a reaction to the existing situation, instead of defining minimum standards based on practical experiences and/or predictions of potential trends.

II. Modern/advanced approach in the safety risk management

Unlike the traditional approach, the modern approach to risk management is aimed at the active prevention of adverse events (safety violations). It is important to emphasize that this approach builds on the obligations that states, regulatory agencies, and other organizations accept through the application of international and national standards and recommended practices. In addition to adequate enforcement, in order to manage risk, it is necessary to harmonize other important factors such as:

- Application of scientific methods for risk management
- Establish a safe environment based on the exchange of information at all levels
- Training and licensing of safety personnel
- Effective application of standard operating procedures, including checklists and briefings
- Establishment of a system for mandatory and voluntary reporting of safety events
- Encouraging those responsible to report incidents and hazards while respecting the principles of safety culture
- Systematic investigation when an unsafe event occurs
- Systematic monitoring of system safety performance in order to reduce or eliminate areas with increased risk

It can be said that after establishing a framework of the safety risk management process, the focus is on the application of scientific methods for risk management. Within the application of scientific methods, one thing is of great importance – data. Namely, effective safety management is highly dependent on the effectiveness of safety data collection and analysis, since their presence is the basis for data-driven decision-making. Reliable safety data and safety information are needed to identify trends, make decisions, evaluate safety performance in relation to safety targets and safety objectives, as well as assess risk [4].

However, data (both historical from similar threats, or current from available databases) on the subject problems is not always available, as the situation is with UAVs in the aviation industry [4]. In such situations, operational experience from industry experts, handled by skilled people within the safety field, is of crucial importance. In advanced safety management approaches, this experience is usually incorporated via brainstorming sessions (as an integral part of methods application), followed usually by the use of fuzzy logic as the
quantification process to convert linguistic expressions into numerical probabilistic values.

3 Safety Risk Management for UAV operations

Safety risk management can be considered a major part of the overall safety management process. This process needs to be performed with respect to principles, standards, and recommendations posed by regulatory agencies. Within the aviation industry, it can be said that there are no two similar safety assessments because each assessment needs to be adapted to the specific safety issue, environment, involved stakeholders, etc. It means that there is a wide spectrum of modern/advanced approaches with a lot of different methods for risk management that can be used. On the other hand, the generic safety process includes the same logic. Figure 1 illustrates the generic process that should be followed within safety assessment when a new safety problem arises, in this research UAVs operations.

3.1 Safety issue

The first step “Safety issue” means the problem identification, as well as the problem description. Usually, problem identification is connected with an increased number of reported events in which safety is compromised. Moreover, when new technology is introduced, like in the case of the UAVs in the aviation system, it is of great importance to conduct safety assessments on predictive basis. This manner is under the principles of the modern risk management approach.

For illustration, if the “positive” UAV usage is considered, for example, the use of UAV for inspection of runway contamination, the included airport authorities should perform SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis [5] for exploring the positive and negative side of introducing new technology, in which manner the safety problem can be identified.

3.2 System description

After the safety problem is identified, the following step includes a system description. In terms of UAV operations, it is needed to analyze intended operations and the environment in which these operations are planned.

The UAV operations have a very different concept compared to manned civil aircraft and operate in a very different environment (day, night, clear weather, complex weather) including the different airspace (controlled, uncontrolled) and the different areas (airport vicinity, urban populated area), so it is important to define system borders that are analyzed.

Regarding intended operations, UAVs originally developed and used for military purposes, have found applications in many civil sectors during the last decade. Depending on the onboard equipment, mentioned applications have been gradually expanding across leisure, commercial and governmental fields from surveillance and rescue operations, to delivery and people mobility [6].

![Fig. 1. Generic safety assessment process](image-url)
3.3 Hazard Identification, Risk management, Safety Performance and Safety Improvement

After the definition of the system and its environment, the following steps include: “Hazard Identification”, performing the “Risk Management” process to access risk emerging from those hazards, checking results with the system “Safety Performance”, and for risks that are not with respect of the target level of safety, taking actions within “Safety Improvement” process.

The following chapter discuss different methods/models that should be taken within the “Risk Management” step.

3.4 Methods/Models for UAV risk management

It is mentioned that in civil aviation, the modeling of safety risks is in the most cases performed using one of the models/methods within the four accepted groups: Causal models/methods, Collision models/methods, Human error models/methods, and Third-party risk models/methods. Depending on the nature of the safety issue and the subject who performs the risk management process, different methods can be adequate. The following examples propose models/methods that will be adequate for different situations:

Example 1

If positive use of UAVs is considering from the aspect of the airline who wishes to introduce them

in their processes (for example for aircraft visual inspection), an adequate approach will be the use of the HAZOP (Hazard and Operability) methodology that aimed to identify potential hazards and operability problems caused by deviations from the design intent of both new and existing processes [1].

Example 2

If it is considering the failure of a technical system that is involved in the UAVs operations (for example the collision avoidance system), an adequate approach will be the use of the FTA (Failure Tree Analysis) methodology [7]. A Fault Tree is a graphical representation of the logical relations between the fault and its causes. The structure of the “tree” provides a mathematical basis for combining the probabilities of individual events to determine the overall risk.

Example 3

If the use of the UAVs is considering for purposes that include a high risk of mid-air collision (MAC) with manned aviation (for example for the runway pavement inspection), an adequate approach will be the use of Reason’s model of accident causation [5]. It is widely acknowledged that accidents in complex systems occur owing to the concatenation of multiple factors. Complex systems contain such potentially multi-causal conditions. Moreover, system’s vulnerabilities are often “latent”. The reason model shows how accidents could be seen as the result of interrelations between real-time unsafe acts by front-line operators and latent conditions.

As within introduction section said, to respond to specific threats quickly, the regulatory agencies and involved entities tend to develop specific methods/approaches. In practice, methods developed by joint ventures result in advanced, specially-designed risk management approaches. Such approaches are presented in the following section.

4 EASA Risk Management Approaches for UAS operations

In recent years, the European Union Aviation Safety Agency (EASA) began to develop a regulatory framework for all kinds of Unmanned Aerial Systems - UAS. In traditional manned civil aircraft, critical failures pose a high risk for humans such as pilots, cabin crew, or passengers. For UAS, the potential risk of fatalities and damage to critical infrastructure depends on the actual operation in combination with the operational environment. Therefore, the focus of the regulation can be changed from an aircraft-centric risk assessment to an operation-centric risk assessment [8].

With such focus, the EASA introduced three new UAS categories included in a new regulatory framework: [9]

- The Open category covers low-risk operations. This category requires only a few operational rules, such as “stay away from people”, as well as
product safety requirements and mass limitations.

- The **Specific category** covers medium-risk operations, for which authorization from a national aviation authority is required.

- The **Certified category** covers operations with higher risks that are comparable to risks in manned aviation. Hence, the requirements to obtain authorization under the Certified category are quite similar to those of manned aviation.

Mentioned regulatory framework includes a recommended methodology for risk management. Namely, in the Specific category, a risk assessment has to be carried out to attain operation permission from the competent authority. The risk assessment considers the risk not only of the operation but the operator's competencies and UAS performance and characteristics as well. One acceptable means of compliance to perform such a risk assessment is the use of the SORA methodology [10].

### 4.1 SORA Methodology

Specific Operational Risk Assessment (SORA) is the methodology developed by JARUS (Joint Authorities for Rule-making on Unmanned Systems). The SORA present a novel approach to how to safely create, evaluate and conduct UAS operation. It presents a multi-stage process of risk assessment that focuses on assigning to a UAS-operation two classes of risk, a ground risk class (GRC) and an air risk class (ARC) [11].

The concept is based on the idea of the “hazard” that a UAS operation could become “out of control”. It looks at the “threats” that could cause this loss of control and the impacts (or “harms” as it calls them) that it could have. SORA enables the operator to specify the barriers and mitigations to these threats and impacts that have been put in place to minimize these risks [11]. A schematic representation of the SORA concept is in Figure 2. In such an approach, there can be found logic of the known method/model Event Tree.

- **Fig. 2. SORA Concept** [11]

To facilitate the SORA process, additionally, the so-called Standard Scenarios (STS) may be developed for certain types of operations, with known hazards and acceptable risk-mitigations. The STS may then be used by operators and regulating authorities as a template to reduce the amount of work involved with approving UAS-operations [12].

#### 4.1.1. Scope and applicability

The SORA could be used to evaluate safety risks involved with the operation of UAS of any mass, any size or performance, operating anywhere [13]. On the other hand, the carriage of people or dangerous goods on board the UAS has not been covered. Additionally, risks of collision among UAS are not addressed. Until now, security and privacy also have not been covered.

Carrying out SORA might be complex but this is always proportionate to the complexity (and initial risk) of the operation. Overall, it can be said that the main idea of SORA is to establish an easy-to-use qualitative risk assessment for UAS operations.

### 4.2 MEDUSA Methodology

Methodology for the U-Space Safety Assessment (MEDUSA) provides a structured and systematic way of determining what happens in an airspace volume, and how it is organized. MEDUSA follows a holistic approach by not only considering the operators’ viewpoint (as proposed in SORA) but by extending the scope to airspace safety. The airspace safety assessment takes into account, among other

---

1 U-Space is a set of new services relying on a high level of digitalization and automation of functions and specific procedures designed to support safe, efficient and secure access to airspace for large numbers of drones. [https://www.sesarju.eu/U-space](https://www.sesarju.eu/U-space)
sources of information, the airspace design, the ATS service provision, and the available U-space services [14].

With such an approach, MEDUSA includes a process for integrating individual SORA assessments, to help obtain insight from multiple SORA assessments sharing the same volume of airspace. The MEDUSA methodology, focus on identification and evaluation of risks from “success” and “failure” approaches [14]. The “success” approach evaluates what requirements or mitigation means are necessary to reach the required level of safety in the volume of airspace considered. In this case, the positive contribution of U-space to aviation is addressed by assessing how effective these U-space services would be when everything is working as intended. Opposite, the “failure” approach (negative effect of U-Space on the risk of an accident) assesses system-generated risks of the U-Space services, including systems and procedures.

In relation to the risk determination, three areas are proposed to assess the mitigation level provided by U-space services: [15]

- Level of mitigation of air risk (unmanned-manned / unmanned-unmanned)
- Level of mitigation of ground risk (prevent fatalities on the ground and damage to critical infrastructure, including aviation infrastructures like Control towers, Ground Navaids, etc.)
- Level of mitigation of incursion into “no-fly zones” (airspace infringement).

It can be said that the development process helps ensure a clear overview of current operations, identification of positive and negative aspects within considered service, as well as, a basis for airspace and/or procedures changes. The Figure 3 presents MEDUSA concept.

5 Conclusion

The technology of unmanned aerial vehicles (UAV) has increasing potential to compete successfully with more traditional alternatives in a number of sectors including commercial, governmental, and leisure purposes. However, this innovation brings high risk to the manned aviation industry, and also to third parties on the ground. The present paper gives an overview of the risk management approaches within the aviation industry, with a focus on the approaches for the safety threats that arise from UAVs operations. Opposite to the traditional approach, that is related to the reactive actions, the modern/advanced approaches are focused on proactive actions in order to prevent unsafe events.

In addition to the implementation of the common-known methods/models, in order to respond to specific threats in a quick manner, the regulatory agencies and involved entities tend to develop specific methods. In practice, these methods developed by joint ventures result in advanced, specially-designed risk management approaches such as SORA and MEDUSA methodology. The SORA methodology is focused on the operations of the UAVs from the operator’s point of view and helps establish an easy to use qualitative risk assessment, while the MEDUSA methodology is focused on airspace safety and helps ensure a clear overview of current operations, identification of positive and negative aspects, as well as, the basis for airspace and/or procedures changes. Despite the fact that both methods are in the early stage of the implementation, it can be concluded that these two methods present a good practice to deal with risks that arise from the UAV operations, but also that those methods would speed up the process of integration of the UAVs in the aviation systems. Future research will be related to the analysis of the outcomes of SORA and MEDUSA implementation.

References


