Safety Science 111 (2019) 7–16

Contents lists available at ScienceDirect

Safety Science

journal homepage: www.elsevier.com/locate/safety

RPAS conflict-risk assessment in non-segregated airspace

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ARTICLE INFO

Keywords:
Air transport
RPAS
Conflict-risk assessment
Non-segregated airspace
Airspace planning

ABSTRACT

The efficient and safe introduction of Remotely Piloted Aircraft System (RPAS) in non-segregated airspace requires a thorough assessment of all operational elements. In this paper, we dealt with the safety problem that arises from the integration of RPAS jointly with conventional aircraft in non-segregated airspace. The authors propose a framework and methodology for airspace design and planning purposes based on a conflict-risk method. This method compares a target level of safety (base-scenario without RPAS) with the calculated level of safety (scenario with RPAS). Moreover, the framework proposes an in-depth assessment by identifying geometrical and operational factors that may affect conflict risk. These conflict-risk factors are critical for RPAS integration and must be assessed to detect relations between them and conflict risk. Moreover, we have performed a sensitivity analysis to assess how RPAS average speed affects conflict risk. A real air traffic volume is studied to characterise a conflict-risk indicator, and different permutations to the base-scenario study the RPAS integration all over airways. Results confirm the validity of the methodology for planning purposes and the viability of RPAS integration without a significant impact on safety but with several restrictions to the RPAS airway distribution.

1. Introducción

The integration of Remotely Piloted Aircraft System (RPAS) into non-segregated airspace is hugely relevant to the Aviation community. In the last years, many regulators, organisations, administrations and researchers have increased their efforts to promote this integration (Dalamagkidis et al., 2008a, 2008b; Oswald and Hershey, 2007; Román-Cordón et al., 2017). Despite the potential benefits of operating RPAS in the European airspace, there is a lack of one standard and consolidated regulation (EASA, 2017, 2015; ICAO, 2015, 2009). Moreover, almost every country has developed their regulation and different barriers to allow operating RPAS in their airspaces. A complex and full of pitfalls regulation do not encourage a free operation of RPAS either the development of the required techniques (Clothier et al., 2011).

Safety is one of the primary concerns preventing progress on RPAS integration. A review of the regulations related to RPAS reveals that administrations have developed a regulatory framework for RPAS operation which demands a risk assessment (EASA, 2017; FAA, 2017). RPAS risk assessment has focused on the evaluation of the risk for third-party pedestrians and second-party airspace users (Clothier et al., 2015a, 2015b). In Melnyk et al. (2014) a third-party casualty risk model for RPAS operations is presented to assess the risk to bystander due to RPAS operations. Similar to this work, Clothier et al. (2007) studied a collision-risk model for RPAS to assess the risks to people and property on the ground. However, this ad-hoc safety point of view is visibly individualist and do not contemplate the impact of RPAS integration in non-segregated airspace from the Air Traffic Management (ATM) perspective.

RPAS integration in shared airspace requires a holistic standpoint of the impact on ATM. Regarding the issue of safety, two underlying questions should be tackled beforehand. First, which is an acceptable limit for a safe RPAS operation; and second, how the risk level should be measured.

The first point questions whether the operational concept must be kept or not, i.e., it is required to maintain the same Target level of Safety (TLS) for conventional aviation or to modify it with RPAS inclusions. EASA and FAA assert RPAS introduction must not adversely affect safety (EASA, 2017; FAA, 2017), which means that a TLS must be maintained or reduced but never increased. Several studies estimated the actual safety levels of an RPAS mission (Clothier et al., 2015a, 2015b; Dalamagkidis et al., 2008a, 2008b; Lum and Waggoner, 2011).

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https://doi.org/10.1016/j.ssci.2018.08.018
Received 27 March 2018; Received in revised form 17 August 2018; Accepted 23 August 2018

Nomenclature

$\alpha^{i,j}$	angle shaped by airway *i* and *j*
$d^{i,j}$	critical section at airway *i* influenced by airway *j*
FL	flight level
H_{min}	vertical separation minimum
i	airway
j	airway
k	airway continuity
L^i	length of the airway *i*
L_{min}	longitudinal separation minimum
n	crossing point
$N_{CP_n}^{i,j}$	number of conflicts at crossing point *n* for airways *i* and *j*
N_{CP_n}	number of conflicts at crossing point *n* for every airway pars
NM	Nautical Miles
P_{exp}^i	exposure probability of an aircraft flying the critical section of airway *i*
$P_{CP_n}^{i,j}$	conflict probability at crossing point *n* for airways *i* and *j*
P_{CP_n}	conflict probability at crossing point *n* for every airway pars
Q^i	aircraft density (number of aircraft per hour) at airway *i*
Q_{max}^i	maximum aircraft density (number of aircraft per hour) at airway *i*
R	conflict risk per air traffic volume
t^i	time required to cover the airway*i*
$\tau^{i,j}$	exposure time flying airway *i* influenced by airway *j*
TLS	target level of safety
$\overline{V^i}$	average speed of aircraft at airway *i*

These studies attempted to quantify the fatalities caused by RPAS failures, collateral damages overpopulation densities and the TLS required for the mission. The strong point of these methods is that they can ensure a safe level of an individual mission. However, their strong point is as well their weakness because they are not valid methods for an overall analysis of RPAS integration. Realistic and reliable risk methods must be developed or adjusted to allow further integration and development of RPAS in a safe environment.

The second question is more challenging to answer because still there are no agreed-upon risk models to assess airspace planning and design. Since the sixties, different collision risk models have been developed to ensure a safe aircraft operation (Reich, 1966a, 1966b). The International Civil Aviation Organization (ICAO) determines risk models must underlie safety pillars on the subject of a previously characterised TLS (ICAO, 2001, 1998). An in-depth review of risk and safety modelling in civil aviation can be found in (Netjasov and Janic, 2008). In Persiani and Bagassi (2013), the authors proposed a route planner for the integration of RPAS but they focused on the development of conflict detection and resolution algorithms. Most of these methods address to calculate a TLS depending on operational features that affect primary factors of airspace design (Tang et al., 2016). In this way, no previous report on RPAS integration in non-segregated airspace can be found in the literature, and there is no research on explaining how the decision of a fixed TLS affect the number of RPAS that can be introduced in air traffic volume.

The research described in this paper aims to adjust a conflict-risk framework for airspace design for RPAS integration in non-segregated airspace. The goal is to calculate a standard TLS that allows capping the safety level of airspace and assessing how it varies with the introduction of RPAS. It is important to note that the framework in this paper does not develop a new conflict-risk methodology but perform some modifications to the proposed method by Netjasov (2012a). However, what literature is lacking today is the assessment of RPAS integration using a conflict-risk methodology. In this way, a risk and capacity assessment will allow calculating the number of RPAS that can be introduced in an air traffic volume without adverse consequences for safety. A further aim is to assess how the airspace complexity affects the conflict risk depending on operational and geometrical factors as well as to define restrictions for the RPAS introduction. Moreover, a sensitivity analysis focus on assessing how RPAS average speed affects conflict risk. The RPAS introduction is an on-going process which cannot be stopped, and it is unquestionable the need to study the RPAS impact on ATM and to provide the help required for achieving this operational change, finding the balance between capacity and safety.

The rest of the paper is organised as follows. Section 2 presents a brief description of the proposed framework for airspace planning. Section 3 explains the conflict-risk assessment method to assess the impact of RPAS in non-segregated airspace. Section 4 describes the airspace selected, and Section 5 discusses the results and potential restrictions imposed by RPAS operation. Finally, Section 6 draws conclusions and further research.

2. Framework for RPAS conflict-risk assessment

The basic idea of this research is to assess how RPAS integration in non-segregated airspace affect safety and conflict risk. RPAS present differences with conventional aircraft in terms of weight, size and operational speed. This research focuses on the integration of heavy RPAS. The most typical RPAS is the RQ4A-Global Hawk with an operational weight over 5000 kg. This type of RPAS is similar to Light aircraft regarding weight but with a lower cruise speed (among 250 and 300 knots) (EUROCONTROL, 2015). The primary goal is to develop a decision-support framework for planning airspace. Hitherto, airspace planning and design processes have borne in mind factors as air traffic control workload and capacity, but few studies have appraised risk or safety.

Airspace planning and design is a high-complexity task that increasingly acquires more relevance in a complex system as air transport. Risk and safety concepts cannot be just ignored and must be gradually integrated at every level of air transport system. In this context, ICAO developed the cornerstone for airspace planning and design with the 9689 Manual (International Civil Aviation Organization, 1998). This manual constitutes the pillar to build a safe air transport system from the airspace design and planning to tactical stage. Particularly, airspace design and planning is (perhaps) the most complex task because it appraises every element and factor of the air traffic system – such as separation minima, airway geometry, traffic density, intervention capacity, communication and surveillance requirements among others. This manual presents a methodology to determine the TLS of an airspace. This TLS assesses whether or not an airspace design fulfils a safety indicator of the air traffic system. The integration of RPAS in non-segregated airspace must ensure that the TLS is not exceeded to ensure safe operations. Therefore, RPAS integration joined-up with conventional aircraft can mean that current airspace planning prevents from this new airspace user.

ICAO's methodology proposes that any concept modification (airspace modification or the introduction of new elements) must be appraised with one of these two approaches: the characterisation of a global TLS which ensure air traffic safety (for instance 10^{-9} accidents per flight hour); or the comparison of a safety indicator from a TLS which is considered a reference. This paper follows the second line of action that ascertains a TLS from a real airspace, and the introduction of a new element (RPAS) is compared against it. Hereon, we will determine what are the geometric and operational factors that may favour or inhibit the RPAS introduction and under what conditions.

Finally, this work assumes ideal operational conditions based on a