Human Error in Operating Mini RPAS

Causes, Effects and Solutions

Customer

National Aerospace Laboratory NLR

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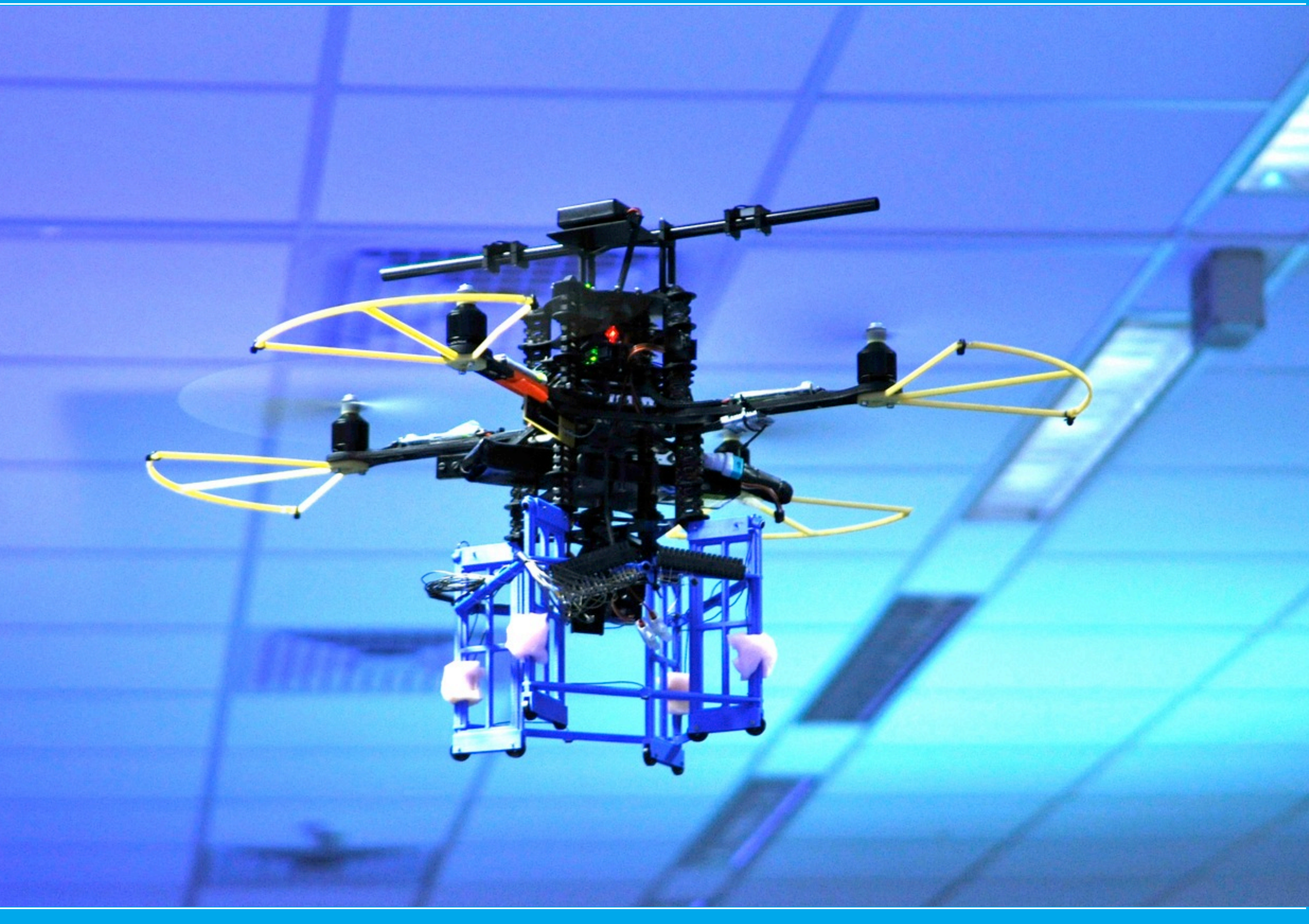

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EXECUTIVE SUMMARY

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Knowledge area(s)
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Training, Missiesimulatie en Operator Performance
Vliegveiligheid (safety & security)

Descriptor(s)
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Safety
UAS
Human Error
Human Factors

Problem area

Although the potential of Remotely Piloted Aircraft Systems (RPAS) is recognized, concerns are also voiced by the regulatory bodies involved over the safety aspects of providing the general public access to the airspace, especially in crowded areas such as West Europe. Dangerous situations such as near misses with both helicopters and commercial aircraft have already taken place. Various restrictions have therefore been put in place on operating mini RPAS in an attempt to maintain safety. Because these restrictions potentially can have a big effect on the prospects of this promising emerging field, it is important to determine whether the restrictions are effective in addressing the problems at hand. The aim of this study is to provide an up-to-date, user-oriented overview of the (human error related) problems in operating mini RPAS.

Description of work

For this study, an operational focussed approach is chosen. First, a small exploratory trial was held to determine the (inherent)

This report is based on a presentation held at the RPAS Civops, Brussels, Belgium, December 10, 2013.

difficulties in operating mini RPAS. Second, specific operational information was acquired by performing observations during operations and interviewing professional RPA operators. Where possible, an operational observation was also performed to contextualize the information. The results from these interviews and observations were analysed and categorised on the basis of standard theoretical human factors frameworks. This study is exploratory in nature. The choice was therefore made to limit the amount of interviews and observations. As a result, the outcomes are presented in a qualitative manner. Frequencies, prioritisation or other quantitative results are thus not presented. Direct associations between the causes and effects can also not be made.

Results and conclusions

The analysis performed on the RPA community revealed that human errors are taking place and that there are several preconditions for latent errors that could directly or indirectly lead to human errors, incidents and accidents. There is a strong presence of violations and organisational factors such as external pressures on the operator to operate beyond rules and regulations. Several knowledge and skill based mistakes were also reported.

Applicability

This study attempts to add to a safe and conscious RPAS community. The RPA community has a fragmented character and includes professionals, amateurs and officials (government). By actively sharing incident and accident data, awareness and knowledge about dangerous situations and platform limitations can be increased among RPA operators. This can potentially prevent some of the knowledge based mistakes. Access to incident and accident data might also increase the awareness of the technical reliance of RPA platforms/components. Although knowledge of the rules and regulations is commonly present among professional RPA operators, it is missing among most amateur or incidental operators. Clear, concise and easily accessible information on the do’s and don’ts for amateur/incidental RPAS operators can help in preventing knowledge based mistakes.

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Abstract

"To err is human", but acceptance among the public and regulators of Remotely Piloted Aircraft Systems (RPAS) in the airspace is fragile and too many incidents and accidents can sway public opinion towards limiting Remotely Piloted Aircraft (RPA) activity. Dangerous situations such as near misses with both helicopters and commercial aircraft have already taken place. Various restrictions have therefore been put in place on operating mini RPAS in an attempt to maintain safety. It is important to determine whether the restrictions are effective in addressing the problems at hand. This paper presents several human errors that occur among current day RPA operations within the current rules and regulations. Direct and indirect causes for these human errors are also identified, as well as causes for RPA incidents and accidents that do not involve human error, such as technical failures. Suggestions for preventing future incidents and accidents are presented.

Keywords: RPAS, Operations, Operator, Human Error, Human Factors, Incidents, Accidents, Analysis.

Content

1 Introduction

The era of unmanned aircraft is upon us. Technological developments in the field of unmanned aircraft over the past decades have made the emergence of affordable and versatile platforms possible. Unlike earlier developments in the aviation sector, the developments in the field of mini Remotely Piloted Aircraft Systems (RPAS) are not driven by the military or governmental domains, nor are they limited to large commercial institutes. The developments in mini RPAS have their roots in, and are largely driven by, non-commercial users/hobbyists and small commercial business. For the first time in aviation history, control of a flying platform is in the hands of the general public. Exotic new platforms are currently being developed. These developments are supported by the 'symbiotic' relationships that exist with other technological developments such as 3D printing and small digital devices like phones, tablets and gaming equipment. The uses for these platforms are almost as diverse as the forms they take: from photography to search and rescue and from geo mapping to pizza delivery (UVS international, 2012).

Although the potential of these platforms is recognized, concerns are also voiced by the regulatory bodies involved over the safety aspects of providing the general public access to the airspace, especially in crowded areas such as West Europe. Dangerous situations such as near misses with both helicopters and commercial aircraft have already taken place (NRC, 2013; ILENT, 2013). Various restrictions have therefore been put in place on operating mini RPAS in an attempt to maintain safety.

Because these restrictions potentially can have a big effect on the prospects of this promising emerging field, it is important to determine whether the restrictions are effective in addressing the problems at hand. This paper presents the study that is performed by the National Aerospace Laboratory (NLR) on the causes and effects of human error in mini RPAS. The aim of this study is to provide an up-to-date, user-oriented overview of the (human error related) problems in operating mini RPAS.

1.1 Mini RPAS and their operations

Mini RPAS are by far the most prevalent of unmanned aircraft as illustrated in the graph in Figure 1. Mini RPAS fall within class I aircraft with a Maximum Take of Weight (MTOW) of less than 150kg. Mini RPAS typically have a MTOW of 2-20 kg, operate up to 3000ft Above Ground Level (AGL) and have a 25km operating radius with Line of Sight (LOS) connection. Mini RPAS can be fixed wing, rotary wing and can sometimes even employ flapping wings. The prevalence of mini RPAS is understandable given the relatively low development costs, highly accessible technology and operational uses.

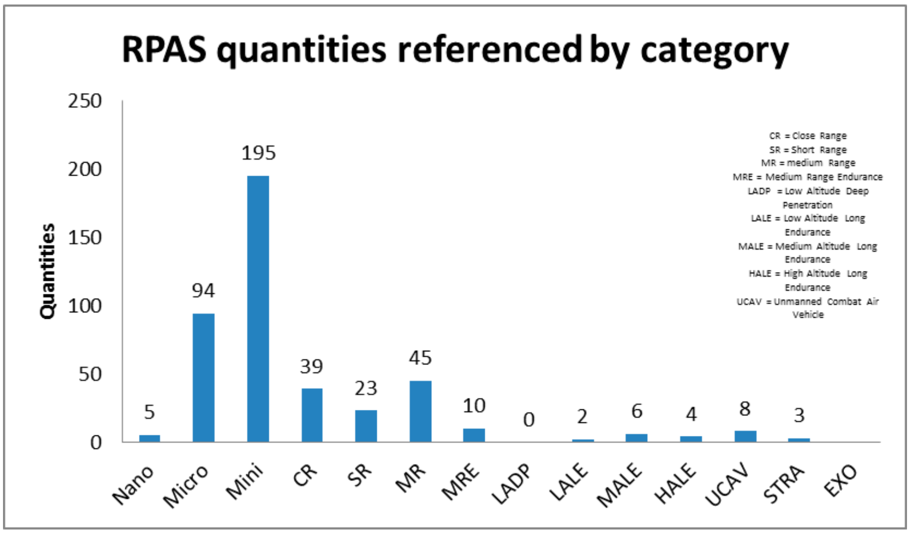

Fig. 1 *Types of RPAS referenced by category (adapted from: the RPAS yearbook 2012-2013)*

Mini RPAS can be used for many different tasks. Most commonly, mini RPAS are used for providing aerial footage. This can be in the form of still photography, motion footage or in the form of mapping geo data using specialized sensors. Other uses for mini RPAS include inspections of valuable or high risk installations, search and rescue and taking (atmospheric) measurements (van Bleyenburgh, 2013).

Along with the many variations of mini RPA platforms, there are many means of controlling a mini RPA (UVS international, 2012). Early versions of RPA control make use of Radio Controlled (R/C) controls typically seen in R/C controlled hobby vehicles and airplanes. R/C control allows fast and responsive input to the aircraft by directly controlling the power and steering. The downside of this type of control is that it requires continuous input from the operator and the operator has to take into account all variables that influence the output of the aircraft such as wind direction, speed and orientation of the platform. There is still a large body of operators that employ this method of control for primary input or as a safety control in case of an unresponsive aircraft. Commercial alternatives to this full manual control of the RPA include tablet/smartphone based applications that allow control of the aircraft using intuitive tilting input. Using on-board sensors, the aircraft maintains heading and position when no input is provided. Manoeuvring the platform does still require constant attention, and orientation issues remain when providing input. Alternatively, a Remote Pilot Station (RPS) can be used to control a mini RPA. RPS's automate the flight aspects of controlling the RPA, by using Global Positioning System (GPS) based waypoint control. On-board sensors and computers stabilize the RPA to maintain the correct position/heading. RPS's allow for precise and easy-to-use control of a RPA, freeing cognitive resources of the operator. The downside of this type of control is its reliance on on-board sensors and the fact that, unless equipped with advanced sensors and a high level of automation, flight paths typically do not take into account objects and obstacles.

The above mentioned means of control is representative for how a significant part of mini RPAS are controlled. However, there are several other input methods and hybrid solutions that are being employed by the community such as game controllers, R/C control with sensor feed or full scale RPS's that are not discussed here.

1.2 Rules and regulations

The regulatory body in The Netherlands is currently still developing and fine tuning the rules and regulations regarding the operational use of (mini) RPAS. The same applies for most European countries, with one or two notable exceptions (e.g. the UK). The European Aviation Safety Agency (EASA) coordinates the development of rules and regulation for RPAS > 150 kg, whereas < 150 kg is regarded a National affair.

The National rules and regulations stipulate that RPA are permitted to fly on an exemption basis. To be able to fly a (mini) RPA, the operator has to (Kruijswijk, 2013):

- Proof reliability of the RPA (design and construction assessment + emergency behaviour cases);
- Be a trained RPA operator (e.g. at EUTA or EURO USC) or comparable (Private Pilot Licence (PPL) / Commercial Pilot Licence (CPL));
- Have type specific training from the manufacturer;
- Have available an operational handbook with, among others, standard working practices;
- Have in place standardised procedures, Safety Management Systems (SMS) and insurance;
- Adhere to the relevant rules of the air.

When these conditions are met, RPAS below 150kg are allowed to operate in Visual Line of Sight (VLOS) of the operator under the following restrictions (see Figure 2):

- VLOS operational area dimensions;
- Maximum distance from pilot 500 m;
- Maximum operation ceiling 400 ft;
- Maximum speed 70 KNTS;
- Not above 'urban' areas (min. 150 m distance);
- Not above people (min. 150 m distance).

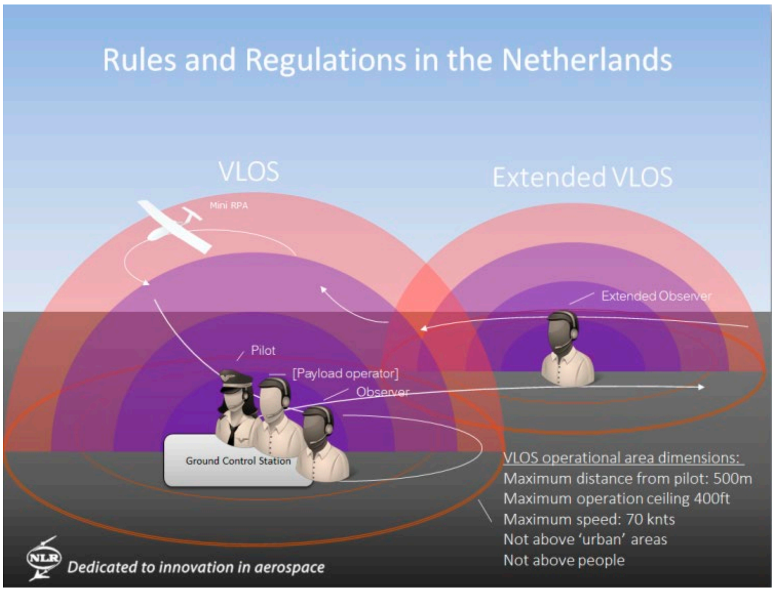

***Fig. 2** Graphic representation of LOS rules and regulations in the Netherlands*

For this, a crew composition of 1 pilot, 1observer and 1 payload operator is required when the payload operator has to operate the payload during flight (e.g. during aerial photography work). Extended Visual Line of Sight (E-VLOS) is possible with one or more extended observers. This extended observer is necessary for operations that extend the boundaries of operations (>500 m). Beyond Visual Line of Sight (B-VLOS) operations are not yet permitted in the Netherlands' airspace for commercial operations with mini RPAS.

2 Research Approach

2.1 Problem definition

The mini RPAS field is fast emerging and fast developing. This presents challenges for both operators as regulators in finding safe and effective working conditions. Too little restrictions and the safety of air traffic and persons on the ground might be compromised. Too many restrictions and the prospects of this field might deteriorate. A clear view of the problems that occur during RPA operations within the current rules and regulations, and the underlying causes to these problems is needed.

2.2 Goals

The goal of this research project is to identify the causes and effects of human error in mini RPAS operations and to identify potential solutions to mitigate these causes and/or effects. The knowledge developed in this project can support and steer the development of new operating procedures, training courses, remote pilot station designs, rules and regulations, manning concepts and provide insight for other (new) R&D projects.

2.3 Research questions

The following research questions are proposed:

1. What human error problems occur during mini RPA (<150 kg) operations under the current rules and regulations?
2. What are the underlying causes related to these human error problems?
3. Can these aspects be addressed in training, procedures, system design or by other means?

2.4 Methods

In order to answer these research questions, it is necessary to understand when and how things go wrong as well as analyse the causes, impacts and relationships between human factors. For this, a mixed academic/operational approach is chosen.

First, general insight on RPA incidents and accidents and underlying human factors is provided by performing a brief literature study.

Second, to provide a baseline for the study, an exploratory experiment into the (inherent) difficulties in operating mini RPAS has been performed by letting a group of 15 participants (cognitive psychology students) operate mini RPAS under different circumstances. Participants were asked to perform a number of RPA operations related tasks such as following flight paths, manoeuvring through a track and providing separation from obstacles and other air traffic. Various control methods were used to represent the different manners of operating. Observation of their behaviour provided clues to the inherent difficulties in operating RPA's.

Third, specific operational information was acquired by performing observations during operations and interviewing professional RPA operators. Interviews were held with three different RPA operators to identify the problems operators face in daily operational use and to determine the underlying causes to these problems. Where possible, an operational observation was also performed to contextualize the information.

The results from these interviews and observations were analysed and categorised on the basis of standard theoretical human factors frameworks. This study is exploratory in nature. The choice was therefore made to limit the amount of interviews and observations. As a result, the outcomes are presented in a qualitative manner. Frequencies, prioritisation or other quantitative results are thus not presented. Direct associations between the causes and effects can also not be made.

3 Results

3.1 Human errors

Several human errors were identified in the investigation that led to incidents/accidents or posed serious risks to the safety of the platform or environment. These human errors can be categorized according to the principal error types as described in Reason (1997) in skill based slips/lapses, knowledge and rule based mistakes and violations. This list is not exhaustive (does not include all possible human errors) and mostly relates to the professional RPA operator.

Skill based slips and lapses

- Tape over elevation sensor

Knowledge and rule based mistakes

- Load wrong flight planning/settings
- Set wrong QNH
- Forget to set home point, resulting in unpredictable RPA behaviour when loss of link occurs
- Forget to reset settings on control input
- Forget to check battery levels
- Forget to take into account environment in setting safe 'return home' flying height
- Misinterpret weather (at altitude)
- Fly into bad weather

Violations

- Fly outside LOS to satisfy customer demands
- Fly in restricted areas/without permit to satisfy customer demands
- Fly with incomplete/incorrect crew composition due to time limitations/financial restrictions
- Exceed flight time limitations resulting in fatigue
- Unnecessarily perform stunts/public shows of airmanship
- Unnecessarily fly too low over terrain/obstacles

3.2 Causes

The study into the causes and effects of human error in operating mini RPAS has uncovered a multitude of causes of incidents and accidents. Although the focus of this research was placed on human error, other causes of incidents and accidents such as technical failures and organisational/professional aspects are identified and presented as well, as they played an important role in the development of incidents and accidents.

Underlying the incidents and accidents of mini RPAS are several different types of causation. Some of these causes (particularly the human factors) can lead directly to human errors, while other relate only indirectly or have a more direct/immediate impact on the safety. The following causes for mini RPAS incidents and accidents have been reported:

Technical failures

- Manufacturing problems
- Hardware malfunctions
- Loss of link

Technical problems with the platform, the control or the connection between control and platform are not uncommon. Most operators routinely perform pre-flight checks on the RPA before commencing a flight, to test whether the platform is technically sound, which prevents most technical failures. A loss of link between platform and control can also occur, resulting in an unresponsive aircraft. Most RPAS feature safety components that will return the RPA back to the landing point in a loss of link event. Manufacturing issues such as problems with weather resistance or fatigue of the various components are more difficult to prevent and control, and often lead to incidents and accidents when they occur.

Human factors

- Training & experience
- Knowledge
- Communication and coordination
- Professional conduct
- Fatigue and boredom

The main contributor to human error in mini RPAS operations are human factors related causes such as lack of training, experience and knowledge. The exploratory experiment indicated that RPA's are inherently difficult to control, and therefore specialized training is necessary. Inherently difficult aspects of operating an RPA include:

- RPA control when under direct (manual) or assisted control mode and when the RPA has a different orientation then the operator (reverse or angled)
- Estimation of distances and RPA orientation in symmetrical mini RPA's (e.g. quad copters)
- Estimation of effects of control inputs on the platform

Deficiencies in knowledge, skills and experience in the operator can cause him/her to unwittingly violate rules and regulations, not foresee problems and inadequately interpret dangerous situations as well as handle emergency situations should they arise. Unfamiliarity with operating the platform (in part induced by the often wide array of different platforms available) can cause the operator to make slips, lapses and errors in operating, increasing the chance for incidents and accidents. The operators' professional conduct is a specific contributor to incidents/accidents. Overconfidence in the operator' own abilities can lead him/her to behave unprofessionally, operating the platform at or above the limitations and taking unnecessary risks. The lack of standardized communication and coordination techniques can lead to a lack of shared Situational Awareness (SA) between the operators. Furthermore extensive, long duration RPA operations can cause fatigue in the operator, as well as boredom under highly automated operation modes. The resulting inattention can cause accidents and incidents.

Organisational aspects

- Violations
- External pressures
  - Time pressure
  - Organisational pressure
- Lack of a safety culture
- Lack of currency training

Organisational aspects are an important cause of incidents and accidents. External pressures such as commercial interest, time pressure or organisational pressure can 'force' a RPA operator into unsafe behaviour. Such violations are by nature less dangerous then mistakes, but are dangerous none the less. Most RPA operators do not have a full safety culture and/or maintain an incidents database. This lack of safety awareness has led to a situation where sharing knowledge and experiences is not the norm. Time pressure can lead the RPA operator to use shortcuts in the pre-flight testing or other checks. Most RPA operators do not perform currency training (yet). This can lead to a loss of knowledge and (emergency handling) skills, resulting in an increased risk of incidents and accidents.

Other

- 'Immaturity' of RPAS field
- Lack of control and supervision

The relatively recent development of the RPA platform from mainly hobby into professional use has seen a fast growth of various different RPA manufacturers and sales agents. As a result, there is a varying level of professionalism, which can result in potentially dangerous aspects such as missing/poor operational manuals and/or incorrect sales advice. Some RPA operators do not possess the knowledge or experience to properly assess the quality of the platform/documentation. Operating without full knowledge of the operation and limitations of the system can result in incidents and accidents. Lastly, the lack of control and supervision on RPA operators creates the possibility for unprofessional conduct to arise and maintain.

4 Discussion

This study was exploratory in nature, and therefore not capable in providing a quantitative analysis of the current problems in RPA operations. The open, operational approach of interviewing operational RPA operators and performing observations did provide important insights in the problems that RPA operators face in their daily operations.

5 Conclusions

“To err is human”, but acceptance among the public and regulators of RPAs in the airspace is fragile and too many incidents and accidents can sway public opinion towards limiting RPA activity. It is therefore in the interest of both the RPA community and the regulators to strive to have as little incidents and accidents as possible.

In this study, we tried to answer the following questions:

1. What human error problems occur during mini RPA (<150 kg) operations under the current rules and regulations?
2. What are the underlying causes related to these human error problems?
3. Can these aspects be addressed in training, procedures, system design or by other means?

The analysis performed on the RPA community revealed that human errors are taking place and that there are several preconditions for latent errors that could directly or indirectly lead to human errors, incidents and accidents.

Striking is the strong presence of violations and organisational factors such as external pressures on the operator to operate beyond rules and regulations. In part these violations can be explained as corner cutting, a by-product of having to be more cost effective than traditional means (such as helicopters). Another factor involved might be the lack of supervision and control of RPA operations.

Several knowledge and skill based mistakes were also reported. These mistakes are most likely related to the experience levels of the RPA operators. Because the RPAS field is still relatively young, it is important to pay extra attention to the training and maintenance of skills, knowledge and attitudes among RPA operators. Furthermore, professional communication and coordination, Crew Resource Management (CRM), teamwork and safety mindedness should be practiced by all crew members to increase safety.

The RPA community has a highly fragmented character and includes professionals, amateurs, official (government), who are safety aware/unaware, profit oriented, etc. By actively sharing incident and accident data, awareness and knowledge about dangerous situations and platform limitations can be increased among RPA operators. This can potentially prevent some of the knowledge based mistakes. Access to incident/accident data might also increase the awareness of the technical reliance of RPA platforms/components.

Although knowledge of the rules and regulations is commonly present among professional RPA operators, it is missing among most amateur or incidental operators. Clear, concise and easily accessible information on the do’s and don’ts for amateur/incidental RPAS operators can help in preventing knowledge based mistakes.

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