

Unmanned Aircraft System Pilot/Operator Qualification Requirements and Training Study

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Abstract. With the rapid development of Unmanned Aircraft System (UAS) technology, UAS has become indispensable in military and civilian field. Growth in number of UAS and activity has required soaring demand for UAS pilot/operator who has become a hot profession in aviation. In this paper, the UAS classification and unique characteristics of operation are stated firstly. Then, considering current requirements about UAS Pilot/Operator qualification issued by aviation authorities in U.S, UK and China, the general and special qualification requirements are analyzed, which includes professional quality, medical requirements, psychological evaluation, training requirements, operating experience and cooperation. Furthermore, based on differences between UAS and manned aircraft pilot training, the training contents and methods, especially human factor and physiological health, are discussed, which is meaningful and helpful to selection and training of UAS pilot/operator.

1 Introduction

With rapid development of technology, Unmanned Aircraft System (UAS) has been developed from auxiliary force to main air power which could execute surveillance, reconnaissance, electronic intelligence, attack and strike and so on. Meanwhile, UAS has been widely used in civilian application, such as environmental monitoring, aerial mapping, meteorology, firefighting, border patrol, fishery protection and law enforcement. Nowadays, UAS has become indispensable in military field as well as civilian.

Data from FAA showed that over 19000 unmanned aircrafts flew in U.S. skies to conduct aviation activities in 2012. FAA predicts that 30000 unmanned aircrafts will be flying in U.S. skies in 2030[1]. Almost one out of every three aircraft used by the U.S. military is a drone [2]. The U.S. Air Force trains more drone pilots than it trains pilots of manned bombers and fighters combined. It also trains more drone pilots than any other branch of the military. But 1 out of 5 PRV pilot training slots went unfilled [3]. The UAS industry is expected to generate an estimated 100000 to 200000 jobs in next decade. Meanwhile, universities like Kansas State University, University of North Dakota, Embrey-Riddle Aeronautical University are offering bachelor degree in UAS. Some aviation enterprises such as CAE and Northrop provide UAS operator training program as well. In China, Civil Aviation Administration of China (CAAC) estimated that the number of UAS pilot is going to soar over 30000 in near future, but currently there only 700 operators having UAS pilot certificate, which could not meet the demand of market. Now only 27 certification bodies authorized by CAAC have been

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qualified to entitle UAS pilot certificate, which is mainly for small UAS. As demand increasing, UAS pilot/operator will be a hot professional career.

This study is mainly for UAS pilot/operator qualification and training. Firstly, classification and operation characteristics of UAS are stated. Then, according to requirements in current regulations, the requirements of UAS pilot/operator qualification are discussed. Finally, the last section proposes the training method and content, especially in human factor and psychological health. All of these will be meaningful for UAS pilot/operator selection and training.

2 UAS Classification and Operational characteristics

2.1 UAS Classification

Currently, due to variety of weight, size, performance and operating characteristics, there is no widely accepted classification of UAS. Generally, UAS are classified in terms of maximum take-off weight, altitude, endurance, typical use and operational radius, as shown in table 1[4].

Table 1. UAS Classification

Category	Weight	Altitude	Radius	Endurance	Typical Use
Micro	<2kg	Up to 200ft AGL	<5km	<1h	Reconnaissance, Inspection
Mini	2-20kg	Up to 3000ft AGL	<25km	1-2h	Reconnaissance, Surveillance
Small	20-150kg	Up to 5000ft AGL	<50km	1-5h	Surveillance, Intelligence,
Tactical	150-600kg	Up to 10000ft AGL	100-300km	4-15h	Reconnaissance, Surveillance
MALE	>600kg	Up to 45000ft AGL	>500km	>24h	Surveillance, attack , Reconnaissance
HALE	>600kg	Up to 60000ft AGL	Global	>24h	Reconnaissance, signal relay, Surveillance

2.2 Operational characteristics

Now, as most of UAS are controlled through datalink, the UAS operation has its own unique characteristics. Firstly, since the UAS Pilot/Operator manipulated vehicle by datalink on the remote control station which is located in hundreds or thousands miles base, it is obvious that there is high demand for bandwidth and latency, which has significant effect on mission operation. The more autonomous the control is, the more demanding operator requirement is. Secondly, the endurance varies from several minutes to over 24 hours as well as the operating environment is also complex due to different circumstances. For example, for HALE, pilot/operator should monitor the screens showing vital parameters of the whole system which is boring and dull. Thirdly, any mission for UAS could not be done successfully by individual and must be completed cooperatively by a team of operators, which is shown in previous research [5]. It is well known that there are six operators who monitor 13 screens and work with 6 workstations in Global Hawk Control Station in order to finish intended mission.

Furthermore, compared with manned aircraft pilot, the UAS pilot/Operator, who is not on board and just controls vehicle in Ground Control Station (GCS), could not get the same quality and amount of information. In another word, for UAS pilot/Operator, who loses most sensory information like vision, sound and kinetic feeling, there is no direct feedback from flight environment such as weather,

smoke, vibration of aircraft and pull of gravity when he moves the controls, while he supervises the aircraft through on-board sensors and cameras down linking information displayed on the screen of GCS. All the information and status of Unmanned Aerial Vehicle (UAV) can only be felt by UAS pilot via radio telemetry or overhead satellite communication and all maneuvers that pilot does are through up link to transmit orders to the UAV. In conclusion, UAS operator feels isolated from vehicle and lacks traditional feedback. Due to various types and unique characteristics, there is more demanding on UAS pilot/operator.

3 UAS Pilot/Operator Qualification Requirements

3.1 Current requirements review

Nowadays, aviation authorities around the world are committed to legislate on rules and regulations for UAS, not only in operation, but also in approval process. European Aviation Safety Agency (EASA) published A-NPA 2015-10 introduction of a regulatory framework for the operation of Drones in 2015, stating that UAS pilot must gain operation certificate. In order to ensure flight safety, Federal Aviation Administration (FAA) formulated interim Operational Approval Guidance 08-01: Unmanned aircraft systems operations in the U.S. National Airspace system in 2008, proposing UAS pilot/operator requirement for the first time, which says that pilot must hold a license and other operator could not have a certificate. In 2011, FAA published Order 8130.34B Airworthiness certification of unmanned aircraft systems and optionally piloted aircraft, which requests that UAS pilot must hold and be in possession of, at a minimum, an FAA private pilot and a valid second-class(or higher) airman medical certificate. Section 333 of the FAA Modernization and Reform Act of 2012 also addresses that UAS pilot must hold pilot license, medical certificate or valid driving license. Small UAS Notice of Proposed Rulemaking (NPRM) issued by FAA in 2015 claims clearly qualification and obligation of pilot controlling lighter UAS under 25kg. For military, the US Army Regulation 95-23: Unmanned aircraft system flight regulations, requiring that UAS operator should be trained and evaluated. DEF STAN00-970 Design and Airworthiness requirements for service aircraft Part 9 UAV system issued by UK military defense in 2013 points out that UAS operator does not have the experience of manned aircraft. In 2002, the Civil Aviation Safety Authority (CASA) in Australia had announced Civil Aviation Safety Regulations (CASR) AC101-1 Unmanned Aircraft and Rockets: Unmanned Aerial Vehicle (UAV) Operations, Design Specification, Maintenance and Training of Human Resources, which requests that an operator intending to conduct commercial operations utilizing UAV must be the holder of an operating certificate. In China, considering UAS development, CAAC issued Civil UAV Pilot Management Interim Regulation in 2013 that is the guidance for Civil UAV pilot and gives specific requirements about pilot certificate, knowledge and operation. In 2015, CAAC issued Interim Administration Procedure for Civil UAS Operation for Commercial General Aviation Activities, which outlines that Operator, who controls UAS greater than 7kg, climbing over 500 meters, radio radius more than 500 meters, must hold training certificate or license. In 2016, Civil Aviation Flight Standard Management Requirements requests that UAS operator should possess corresponding technical qualification and attend professional training and the UAS should be incorporated into daily management of general aviation.

It can be seen that current UAS regulations only request general requirements of UAS pilot/operator. There are no agreed and detailed requirements about UAS pilot/operator qualification. Thus, it is vital to explore qualification for UAS pilot/operator career development.

3.2 Qualification Requirements

According to current airworthiness regulations and interaction between operator and system during operation, several factors should be considered for UAS pilot/operator qualification, including

professional quality, medical requirement, psychological evaluation, training requirements, operating experience and coordination.

3.2.1 Professional Quality

A professional and qualified UAS pilot/operator should possess five aspects of quality, including professional dedication, sense of duty, self-control, enthusiasm for work, logical and rational. Besides, UAS pilot/operator must be at least 18 years old, physical fitness, know well about aeronautical theory and related aviation regulations.

3.2.2 Medical Requirements

Compared with manned aircraft pilot, UAS pilot/operator should have medical certificate, but it is not strict. Of course, it is necessary to have good eyesight, which is not good as manned aircraft's. Medical requirement could be different due to variety of UAS. For small UAS operated in line of sight, a driving medical license could be sufficient. Nevertheless, for larger UAS, operator must hold a valid class two or three medical certificate outlined in 14 CFR part 67 Medical Standards and Certification. For operators, who are responsible for mission design, planning, datalink and payload, the medical requirement could be relaxed due to particular position.

3.2.3 Psychological Evaluation

In recent years, the numbers of accidents caused by pilot psychological problems is climbing, but psychological health is not concerned seriously by airlines. Although International Civil Aviation Organization has paid much attention on this issue, there is still less regulation or research on it. In 2013, FAA published an investigation report about accidents, which shows that there are 8 accidents caused by pilot suicide in 2758 accidents between 2002 and 2012 [6]. According to final investigation report by French Bureau of Enquiry and Analysis for Civil Aviation Safety (BEA), the crash of Germanwings Flight 9525 was deliberately caused by the co-pilot, who showed symptoms of psychotic depression, had been treated for suicidal tendencies [7]. These accidents make airlines and authorities pay more attentions to pilot psychological health.

There is limit about research literature regarding the psychology of UAS pilot/operator, and released UAS regulations do not refer to psychological requirements in qualification requirements. In 2014, U.S Air Force conducted research of psychological evaluation for Remote Piloted Vehicle (RPV) pilot training candidates, and proposed pre-training standardized personality testing for the first time. Personality testing employed the NEO-PI-R, which measures candidates from five major personality domains: neuroticism, extraversion, openness, agreeableness and conscientiousness. The study evaluated 7682 participants who entered manned or unmanned pilot training between 2009 and 2013 [2]. The study revealed that RPV pilot training candidates are more likely to remain calm under pressure, are slower to anger, less prone to feelings of sadness and hopelessness, have higher self-esteem, and see themselves as more capable of handling difficult situations. Now, psychological evaluation has already been used in USAF RPV training candidates, rated pilots and pilot selection, which would help pilot/operator work well and efficiently in long endurance and complex mission environment.

As the level of UAS informatization and automation advancing, the physical workload for UAS pilot/operator is declining, but the mental workload is increasing, especially in emergency, special and crucial mission. Furthermore, psychological problems like stress or anxiety will cause health problem mentally and physically. If these problems are not solved promptly, it will have significant influence on mental health, flight safety and mission accomplishment to a certain degree. Hence, during UAS pilot/operator selection, it is necessary to evaluate psychological state of candidates which contains several factors, such as high levels of conscientiousness, responsibility, achievement orientation, sense of cooperation, emotional stability, resilience, self-confidence, self-esteem, risk tolerance, self-

discipline and excitement seeking, and conduct psychological consultant at regular intervals, which is vital for safety of vehicle, people and asset on the ground.

3.2.4 Training Requirements

For small UAS pilot, it is necessary to pass aviation theory test, participate in simple adaptable training and acquire certificate or license as FAA regulation requests UAS pilot must hold a driving license. For UAS above tactical level, pilot/operator must have four-year degree of aviation or engineering, complete professional pilot training program, learn aeronautical knowledge comprehensively and systematically, and earn enough flight hours to qualify for an entry-level, because complexity and risk of UAS mission increase as technology and application expanding. For UAS operator serving in military, police and government, it is indispensable to hold a pilot license with a certain flight hours. Moreover, confronting with battlefield and crime scene directly, military or police operator should attend psychological health consulting to ensure the mental state achieving required level to perform assigned task better. For larger UAS pilot, manned aircraft pilot should be given top priority to candidate selection, and aircrew training should also be arranged in training program.

3.2.5 Operating Experience

Since UAS operating crew are not onboard, operating characteristics and control mode of UAS are to some extent different from traditional piloted aircraft. UAS crews locate on GCS hundreds or thousands of miles away from the vehicle, while UAS relies on more pre-programmed software instead of control device. To some degree, UAS pilot must finish special training to ensure safety of vehicle under circumstance that crew control system in an isolated environment. For small UAS, operator could lack experience due to operating in visual line of sight. But for larger UAS, especially for application for military or governmental purpose, it is essential to having sophisticated experience to ensure mission success and flight safety.

3.2.6 Coordination

As development and application of UAS has been rapidly expanding in recent years, UAS have more chance to cooperate with UAS, manned aircraft, unmanned ground vehicle, and unmanned underwater vehicle in special mission. It is obvious that UAS pilot/operator should not only be familiar with operation and knowledge of UAS and operating characteristics of other vehicles, but also fulfill systemic cooperation training prior to mission execution.

To conclude, a career as a UAS pilot/operator will be very different in the future and there will be more detail about UAS pilot/operator requirements to be released.

4 UAS Pilot/Operator Training

To some extent, there is difference between UAS and manned aircraft pilot training. Firstly, without human onboard, the UAS operator locates GCS to control vehicle. Secondly, comparing with manned aircraft pilot, there is no physical limitation for UAS pilot and the operating skills are different, which require totally different requirements. Thirdly, UAS is controlled by one crew team, including pilot, payload operator, datalink operator, mission planning operator, and other staff. That needs more demanding on responsibility and training content. Fourthly, different types of UAS highlight different aspects of training. All of these determine that UAS pilot/operator training content and method should be considered carefully case by case.

Like manned aircraft pilot training, UAS pilot/operator also needs more training. Relying on real UAS training has two disadvantages. The first one is the risk. Unlike manned aircraft, when manned

aircraft has malfunction, pilot could take effective actions to mitigate risk. However, the most severe consequence will be crash if failure or fault happens during UAS flight. The second is growing cost when complexity increasing, especially for large UAS. Using real UAS for every training subject will cost more and need more crew assistance. At the same time, training will also result in worn or damage due to improper operation, which could increase maintenance expenditure.

Considering all these factors, the UAS pilot/operator training should include theoretical training, simulator training, small UAV operation, and specialized training, which could cover almost all the training subjects, reduce training risks and costs, improve efficiency and decrease unnecessary damage due to human errors. The basic content and method of UAS pilot/operator is shown in Table 2.

Table 2 the basic content and method of UAS pilot/operator training

No.	Course	subject	Content	Method and equipment
1	Theoretical training	Basic knowledge	Aerodynamic, the principle of Flight, Flight Control, Airspace Management, Flight Rules, Critical meteorological condition, etc.	Theoretical lecture and visit, every topic is taught by experts.
		Introduction about UAS	UAS development, category and application, challenges and future technology	
		Components of UAS	Unmanned Vehicle, GCS, Datalink, Payload, Support Equipment, Human Crew	
		UAS missions	Typical task and intelligence analysis, Mission Planning, Mission Termination Procedures	Psychological health is taught by professional aviation psychologist, and targeted psychological training was integrated in simulation and flight.
		Safety	Risk Analysis, Safety Management, Emergency Scenarios	
		Regulations	FAA, NATO, EASA, UK, Australia, etc.	According to investigation reports of accidents caused by human factor, introducing human factor issues in UAS operation, giving relevant guidance in operation training.
		Case study	Typical investigation reports of UAS accidents, like Global Hawk, Predator, Hunter and Pioneer	
		Psychological Health	Basic Knowledge of aviation psychology, Psychological training, Stress management, Case study	
		Human Factor	Basic knowledge, Human error and safety, Ergonomics, Case study	
2	simulator training	Introduction	Components, Functionality, Operation Procedures	Training simulator, stimulating from mission analysis to path planning, from control to de-brief, guided by professional instructor.
		Operating skill	Basic Operation, mission planning, take-off and landing, emergency disposal, etc.	
		Typical task simulation	Brief and De-brief, simulating, data analysis, paper report	
		Cooperative training	UAS operator team cooperative training on typical mission	
3	Small UAS operation	Flight skill	Technical skill, take-off, climb, cruise, landing and recovery, emergency disposal	Rotor-wing or small fixed-wing UAS, investigation reports from U.S military
		Cooperation	Simulating cooperation with commander, air traffic controller, and other staff	
4	Specialized training	Special subject training	Aiming at special purpose UAS, for example, for UAS designed for forest fire-fighting, extinguishant launch, reloading, payload exchange, fire detecting, etc.	Using special site, special UAS Using trainer aircraft,

		Operation difference	For larger UAS operator, piloting manned aircraft, comparing manipulative difference between UAV and manned aircraft	such as Cesena 172 or TB-20
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According to statistics and investigation reports, psychological health and human error are the two main factors affecting safety. But for UAS pilot/operator training, there is limited research of these. So psychological health and human factor in UAS pilot/operator training will be discussed thoroughly.

A. Psychological Health

Better psychological health could help aircrew relieve fatigue, enhance working efficiency and confront the burdens preferably. Experts in Europe and U.S. point that psychological problem during flight could not be detected in recruiting psychological evaluation. Manned aircraft pilot receive psychological training and counseling at regular intervals. In the same way, the psychological health training should be added in UAS pilot/operator training program. All these training should be instructed by professional aviation psychologist, and the curriculum provision should be set on the basis of mission characteristics, age and current mental health condition, which could help pilot master relevant method and eliminate negative induced emotion. The contents of psychological health training include three parts. Firstly, aviation psychologists introduce fundamental content of aviation psychology. Then on the basis of investigation reports of UAS accidents led by human crew, how important psychological factors in UAS operating are should be discussed. Secondly, aviation psychologists explain current mental training methods, such as Risk Perception and Decision-Making Training, Willpower Mastery, and Self-Psychological Regulating. It is important to train UAS pilot/operator from aspects of feeling, attention, memory and thinking, using flight simulation and real flight. Finally, UAS pilot/operator would make adequate preparation to manage emergency through these training program, which could finally raise working efficiency as well as mitigate mental workload. Lastly, the methods of stress management should be interpreted, which will teach UAS pilot/operator how to adjust his emotion, state, sleep, exercise, self-relaxation regularly. Consequently, UAS pilot/operator could execute designed mission remarkably.

B. Human Factors Issues

Statistics show that nearly 40% of UAV accidents could be attributed to human errors or operating mishap [8]. The study by Barnes and Matz indicated that poor situation awareness was related to operator errors in a series of simulated Unmanned Combat Aerial Vehicle (UCAV) missions [5]. For instance, in which the UCAV crashed, a narrowed attentional focus, especially during targeting activities was partly responsible for the crashes. Simultaneously, pilot/operator’s heart rate and subjective assessment of mental workload also increased. The contrast of single versus two operators pointed that only one person could not control UAS to complete assigned task effectively. Thus, it is necessary to offer human factor program in UAS pilot/operator training project, which is helpful for improving flight safety and performance efficiency, enhancing operator control level and reducing crew mishap. The syllabus of human factor includes four parts. Firstly, from the perspective of UAS pilot/operator, the basic content about human factor should introduce the limitation of human crew in cognitive process, such as vision, auditory, situation awareness, decision-making, attention, workload and attitude. Secondly, from the aspects of design and operating, instructor should present ergonomic influences on UAS operation, such as the human-machine interface, control system, display system, and internal environment in GCS. Thirdly, combining the concept of human error with investigation report of typical UAS accident such as Global Hawk and Predator B accidents, instructor will analyse how human error affecting operation and propose suggestion and measurement for preventing human error. Last part should mainly concerns analysing human factor issues that would affect flight safety and operation efficiency, such as workload, situation awareness, human-machine function distribution, teaming issue and operator control level, and giving relevant advice and training. Through human factor syllabus, UAS pilot/operator will realize the importance of human factor in operation, which will mitigate mishap or accident in UAS operating and enhance the safety, reliability and efficiency of UAS.

From above discussion, it can be seen that the basic training methods and contents are proposed and human factor and psychological health are also introduced thoroughly, based on the current development and application of UAS. As UAS technology advancing and automation increasing, the definition and responsibility of UAS pilot/operator will also be changed, and all of these will propose new requirements on UAS pilot/operator training.

5 Conclusions

As UAS technologies advance, military and civil aviation would rely more on UAS, the future for UAS pilot/operator looks to be more busy and promising than ever before. Before the levels of safety on UAS achieving equivalent to manned aircraft, UAS pilots are still irreplaceable. Now engineers and researchers are paying more attentions to study UAS pilot/operator qualification and training, which could improve level of flight safety and promote development and application of UAS. The Tendency of UAS control mode is that UAS has ability of fully autonomy in the future that reduces workload of UAS pilot/operator and raises more demanding on qualification. It is a long way to discuss UAS pilot/operator qualification and training with more exploration and continuous improvement. As rapid development and wide application of UAS, UAS pilot/operator will play a key role in future aviation.

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