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Important Issues in Unmanned Aerial Vehicle User Education and Training

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Abstract

Unmanned aerial vehicles (UAVs) are aircraft that can be controlled remotely or autonomously without a pilot on the platform deck, with the help of Auto-Pilot and software-controlled flight plans. Unmanned aerial vehicles (UAVs) are a component of the Unmanned Aerial System (UAS). For this reason, those who program the mission pattern of these vehicles in advance, use them by remote command with or without sight, how to act in the face of possible developments during the mission, and who know the UAV technology and working principles well in this context, if the connection with the unmanned aerial vehicle (UAV) is lost, The training of the pilots, who enter the necessary information into the system as a command, in order to complete their mission and return safely to the starting point or to a different place, is very important. A professional and qualified UAV pilot/operator should possess five key characteristics, including professional dedication, sense of duty, self-control, enthusiasm for work, logicalness, and rationality. While preparing personality tests for pilot candidates, it should be based on measuring five main personality areas (neuroticism, extraversion, openness, agreeableness and conscientiousness). In the last 20 years in Turkey, the number and kinds of UAVs used especially in the field of security has been constantly increasing, and the number of national and domestic projects is increasing at a level that can compete with their counterparts in the world. Armed unmanned aerial vehicles (Armed UAV) are used extensively in domestic and international security operations, especially in internal security operations, contributing significantly to the success of the operation and reducing casualties and risks. For that reason, this research is focused on UAV pilots education and training as key personnel of UAV and try to bring front important issues of training period.

1. Introduction

Unmanned aerial vehicles (UAVs) are aircraft that can be controlled remotely or autonomously without a pilot on the platform deck, with the help of Auto-Pilot and software-controlled flight plans. Unmanned aerial vehicles (UAVs) are a component of the Unmanned Air System (UAS). In UAV, it basically includes a control system on the ground and the communication system between the two. UAVs can be operated autonomously in various situations, or they can be operated autonomously by remote control by a pilot, by computers at a fixed location or by piloting an autonomous robot (Figure 1) (Ateş, Düzgün, 2020).

Figure 1. Unmanned Aerial Vehicle (UAV)

Since the UAV pilot/operator manipulates the UAV with the data link on the remote control and sometimes works at the control station, which is hundreds or even thousands of kilometers away, the importance of the system in command is quite high. The more autonomous the vehicle, the more important the need for the operator. In addition, the mission becomes more difficult if the mission duration is too long and the atmospheric conditions are complex. Also, compared to a manned aircraft pilot, being at a remote ground control station has the disadvantages of collecting mission-related information in a timely manner, with the same quality and quantity. In other words, the UAV pilot who has lost contact with the vehicle cannot receive direct feedback from the flight environment such as vision, sound and kinetic emotion, weather conditions (Ateş, Düzgün, 2020).

The UAV pilot can transmit commands to the UAV via radio link or satellite link. As the drone pilot feels isolated, it is more difficult to access information, get feedback and make quick decisions as in conventional aircraft. Considering the wide variety of UAVs, the importance of UAV piloting is increasing (Williams, 2004).

For this reason, those who program the mission pattern of these vehicles in advance, use them by remote command with

or without sight, how to act in the face of possible developments during the mission, and who know the UAV technology and working principles well in this context, if the connection with the unmanned aerial vehicle (UAV) is lost, It is very important to train the pilots, who enter the necessary information into the system as a command beforehand, in order to complete their mission and return safely to the starting point or to a different place (Best, 2013).

With the rapid development of technology, UAVs can be used for intelligence, attack and etc. as an auxiliary force to the air force that can perform operations such as surveillance, reconnaissance, electronics. was used for the purposes. UAVs were initially used for "boring, dirty or dangerous" missions for humans. Although the use of UAVs generally occurs in military activities, depending on the developing technology and needs, it can be used continuously in commercial activities, scientific studies, security services, logistics, cargo transportation and large warehouses, entertainment sector, agricultural field, meteorology, firefighting, fishing, aerial photography. It continues to be used in infrastructure inspections, smuggling and other application areas that are necessary and difficult to access (Wang, Ying, 2018).

2. Materials and Methods

This research is “descriptive”. The main purpose of this research is to give important information, which obtained from different sources and feedback reports about UAV pilot education and training. The data collecting methodology is a “literature review”. The data are collected from national and international aviation literature, feedback reports from UAV courses institutions and General Directorate of Civil Aviation (GDCA) of Turkey, interview with UAV pilot trainers, and from the congress conclusion reports of World UAV Federation. Collected data are grouped as “theme-based”. Descriptive analysis’ techniques are used to analyses collected data, then, reached findings and comments, and conclusions made based on those comments.

3. Discussion

Several factors must be considered for UAV pilot/operator qualification as the operation is conducted based on current airworthiness regulations and the interaction between the pilot and the system. These are technical information about UAV and its components, the degree of professionalism and quality of education received, meeting medical needs, level of evaluation of psychological state and events, duration of user experience and coordination ability (FBEACAS, 2016).

First of all, it is necessary pilot to know the technology, additional equipment, working concept of the UAV, the principles of interaction in the external environment and different meteorological conditions, what and how to do in accordance with the conditions and especially command a high-tech system (Ateş, Düzgün, 2020).

The UAV pilot must have basic knowledge about main components, which are vital for every safe flight. Knowing the main components of a UAV will give pilot extra confidence while using it and it will also helpful for maintenance and inspection of a vehicle. If the pilot has knowledge any flight problems, each UAV component may assist greatly in finding the underlying cause of any flying issues. This one is the best ways to become a highly skilled and successful UAV pilot.

The main components and sub-systems of UAV are; brushless motors, propellers, flight controller (FC), electronic speed controller (EFC), power distribution board (PDB), camera, gimbal, LiPo battery, frame and boom (F), GPS module, R/C receptor (RX), video transmitter (VTX), first person view (FPV), and landing gear (Figure 2) (Uddin, 2020).

Figure 2. Main Components and Systems of UAV

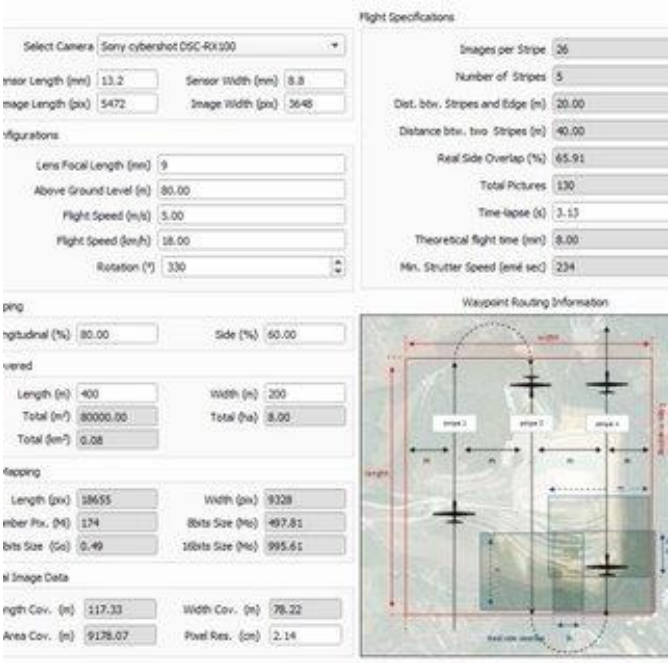
Brushless motors provide neutralization of the turning force produced by the rotating propellers. UAV have two clockwise motors and two counter clockwise motors. That is simply due to Newton’s 3rd Law, which refers that every action/movement has an equal, and opposite reaction. Latest versions of UAVs use a brushless electric motor, which is more efficient, more reliable, and quieter than a brushed motor.

One of the most important parts of the UAV is the propellers. These rotating blades are the blades of the system, the part that creates the airflow that lifts the machine into the air. UAV propellers come in many different shapes and sizes and all serve the same general purpose, but the flight characteristics of each can differ significantly (Become A Drone Pilot, 2020). UAV has two different kind of propellers, each one for each motor direction. Each propeller rotating to push the air down on the airfoil surface resulting in a difference of pressure, so this making the vehicle airborne.

Figure 3. 4-Propeller UAV With Camera

The UAV flight controller takes in inputs from the Global Positioning System (GPS) module, from the sensors, and from the remote controller unit. Then processes it into information

that is given out to the electronic speed controllers (ESC) to control the motors. This part of UAV hence known as the brain of the vehicle. The pilot gives the flight safety parameters via flight controller (Figure 4 and 5).



Source: FAA, 2016

Figure 4. Flight Safety Parameters of UAV

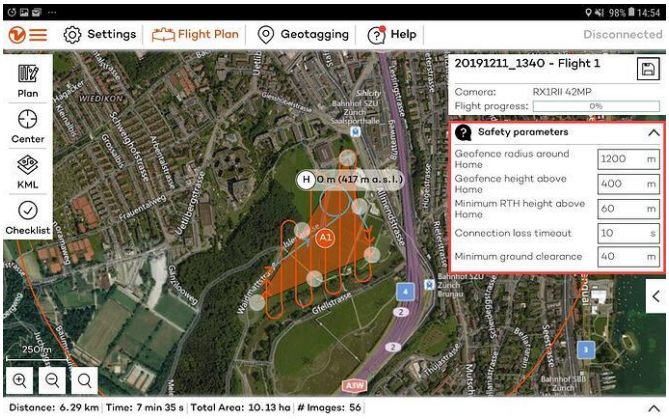


Figure 5. Flight Safety Parameters Entering Via Flight Controller.

The electronic speed controllers (ESC) are connected to the power distribution board (generally the battery) and the flight controller of UAV. As the ESCs receive signals from the flight controller, it changes the amount of power given to each of the motors.

The power distribution board (PDB) is like the motherboard of a computer, the place where all the UAV's electrical components connect and uses power from the battery.

The camera captures video feed, allowing for real-time, first person view (FPV) flight. Gimbal is the mechanical piece that enables movement and stabilization of the camera.

LiPo battery stands for lithium-ion polymer battery, which is a rechargeable battery of lithium-ion technology using a polymer electrolyte instead of the more common liquid electrolyte

Frame is that plastic catching which holds everything together. In many UAVs, the boom is part of the main body.

The GPS module often combines receiver and magnetometer to provide latitude, longitude, elevation, and compass heading from a single device. Without GPS, UAV would have very limited usage. Some military UAVs are GPS-independence to provide security of a flight and keep away from outside effects.

R/C receptor (RX) is the sensor receiving signals from remote controller. Remote controller (TX) provides the link between the pilot and UAV. It looks very similar to toy remote controllers, with the big difference that this has more way buttons and it is significantly more sensible.

Video transmitter (VTX) connects to the camera to transmit video to the first person view goggles or monitor. First person view (FPV) goggles or screens are the devices used by pilots to observe the live video feeds being transmitted from UAV.

UAVs which carry payload comes with a fixed landing gear like helicopter mounted directly to the body. However, the UAVs have retractable landing gear thus allowing a full 360-degree view when in flight. UAVs which have no hanging payload omits landing gear but if it flies in areas where there is long grass, rocks or dusts then either carry a big landing mat or it can be leg height extenders.

The sensor is very important technology in today's world. This part is also important for UAV. A sensor is a device, module, machine, or subsystem to detect events or changes in its environment and send the information to other electronics, frequently a computer processor. In UAV, position and movement sensors give information about its location. Exteroceptive sensors deal with external information such as distance measurements, while exproprioceptive ones correlate internal and external condition. Non-cooperative sensors are able to detect targets autonomously so they are used for separation assurance and collision avoidance. Degrees of freedom (DOF) refers to both the amount and quality of sensors on board: DOF implies 3-axis gyroscopes and accelerometers. The types of sensors are light, sound, heat, chemical, magnetic, and image (Figure 6) (Uddin, 2020).

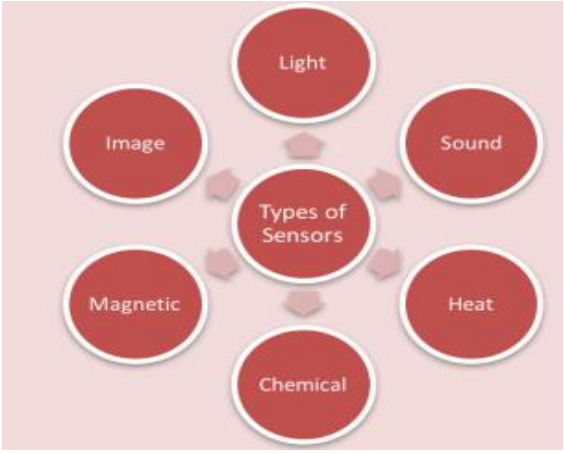


Figure 6. Types of Sensors

Another important issue for pilot to know the meteorology and weather conditions.

The stability of an air mass refers its weather characteristics. When one type of air mass overlies another one, air conditions change with altitude. The characteristics of typical an unstable and a stable air mass can be seen on Table 1 (Uddin, 2020).

Table 1. Air Conditions for UAV Operation

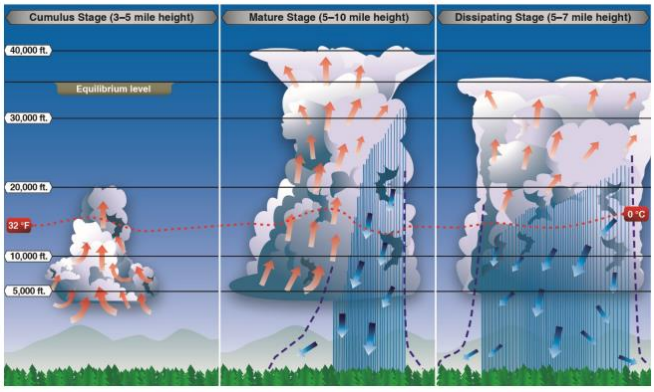
Unstable Air	Stable Air
Cumuliform clouds	Stratiform clouds and fog
Showery precipitation	Continuous precipitation
Rough air (Turbuance)	Smooth air
Good visibility (except in blowing obsructions)	Fair too poor visibility in haze and smoke

Source: Uddin (2020)

To increase the temperature of a substance cause decreases its density. Vice versa, to decrease the temperature of the air cause to increase the density. So, the density of the air varies inversely with air temperature. This condition is true only at a constant air pressure. Both air temperature and air pressure decrease with altitude and have conflicting effects upon density in the atmosphere. However, a rapid drop in air pressure, as altitude increases, usually has a dominating effect. Hence, pilots can expect the air density to decrease with altitude.

Before starting, needs to check temperature, wind, fog and cloudiness, and keep in mind that if the temperature falls below the freezing point, this may have a negative effect on the batteries. In temperatures below the freezing point, pilot will need detailed knowledge of the batteries; make sure pilot is familiar with how batteries are affected. Also, make sure to keep them heated before start. At freezing temperatures and humid air, ice may build up on the propellers, dramatically increasing the risk for crash. Keeping in mind, that wind speed often increases with altitude (FAA, 2016).

The most dangerous air condition for UAV operation is thunderstorm. Downdrafts characterize the dissipating stage of the thunderstorm cell can be seen in Figure 7 and the storm dies rapidly. Whenever rain has stopped and downdrafts have abated the dissipating stage can be completed. When all cells of the thunderstorm have completed at this stage, only harmless cloud of UAV operation remains.



Source: FAA, 2016

Figure 7. Altitude and Cloud Conditions for UAV Operation

In aviation, situational awareness (SA) is often discussed. Situational awareness refers to the pilot being in control of the entire situation – the flight, the UAV, the surroundings, the airspace, etc. The pilot must be able to understand what happens during the flight and what may affect it: other pilots, weather conditions, the UAV's and the remote pilot's limitations. The better the situational awareness, the safer the flight.

Another important issue for UAV pilot is to know how actually UAV flies. Directional control the most popular UAVs available today are multi-rotors. They keep UAV stability by varying the speeds of each propeller. Directional control in an UAV is succeeded via changing the angle of attack of the propellers, the same as a chopper. However, this change in attack is accomplished by slowing some of the rotors (FAA, 2016).

There are two vital sensors, which are required to be able to make it smooth flight for movements of a multi-rotor UAV. The accelerometer detects linear movement, which means to move in a straight line, and the gyroscope detects rotational movement, which means to move around a line.

To be able to control of UAV remotely, UAV pilot must have capability to communicate with it wirelessly. Radio waves are an invisible form of wave on the electromagnetic spectrum. To work radio to work, UAV pilot must have a transmitter and receiver to send and to get the messages. Important point is transmitter and receiver need to be tuned to the same frequency. Most UAVs today are Wi-Fi enabled, so that they can broadcast video to a computer, tablet PC, or smartphones. Some UAVs also use Wi-Fi for remote control through a tablet PC or other mobile applications.

The GPS is mainly used to communicate location back to a mobile application. The GPS also can be used for pre-programming of the routes. Once programmed, if the UAV loose communication, it is possible to fly in sequence to each of the GPS locations identified in advance by the pilot.

Another issue for UAV pilot is considering the environment. Many areas and airspaces are closed, either during certain periods or constantly. Pilot may be able to unlock some of them with an app or via air traffic control towers, while some of them will always stay closed. It is important that pilot is very familiar with the environment and the route in order for the flight to be as safe as possible. Pilot should not forget to notify people nearby that the flight will happen.

UAV always flies within pilot's visual line of sight. One concept that pilot may come across when flying UAV is visual line of sight (VLOS). In addition to being able to see UAV while flying, keeping the UAV within pilot's visual line of sight means that pilot must also keep a safe distance to people, animals, buildings, vehicles and other aircraft. It is never allowed to fly higher than 120 meters.

UAV pilot should follow some procedures during the flight operation. First one is compass calibration. Pilot should always follow the manufacturer's instructions for compass calibration in the drone's manual. If no chance to access to the manual and it is needed to calibrate the compass, it can be followed the generic instructions. First think is removing watches and other metal objects from clothing and body and turning on the radio transmitter. Second step is placing the UAV outdoors on a metal-free surface and switching the power on. Until waiting at least six satellites are visible in the app or on the radio transmitters display, to start calibration in the app (if applicable) or via the radio transmitter. After then, it should be put the radio transmitter aside, standing behind the UAV with the camera facing away from pilot, then lifting the UAV and holding it with straight arms. After this, pilot makes a complete clockwise rotation in about 5–7 seconds and "tip"s the UAV forward so that the camera points straight down towards the ground. At the last step, completing a new rotation at the same pace as before and putting the UAV down and ensure that the calibration is completed.

After the compass calibration, it must be controlled radio transmitter and UAV batteries be charged fully, any frequency interferences that affect video and receiver, the photo and video equipment mounted correctly, the take-off position secured, airspace restrictions. After that starting the radio transmitter

first, starting the camera system, control sticks in neutral position, and control the direct remote identification system work properly (FAA, 2016).

During flight, pilot must keep fingers on the radio transmitter at all times. UAV shouldn't fly higher than 120 metres above the ground (in uncontrolled airspace) and keeping the UAV within pilot's visual line of sight (Figure 8).

Figure 8. UAV Pilot and Mobil Flight Controller

To rise to optimal altitude to reduce risks and noise. Avoiding flying over people, animals, electrical wiring, buildings, and no disturbing ongoing rescue operations. Moreover, immediately landing the UAV if a helicopter or other low flying aircraft is approaching.

For landing, it should be checked the landing area for obstacles or any other hazards and landing the UAV at a safe distance from obstacles and people. Then switch the UAV off.

After the flight, if needed, pilot should inform the air traffic control tower that flight is completed. To switch off the camera and any other equipment. Carrying out an ocular examination: looking for damage and abnormal wear and tear, removing the batteries, recharge and store them in a safe place.

A professional and qualified UAV pilot/operator should have five important key characteristics, including professional dedication, self-control, sense of mission, logicalness, rationality, and enthusiasm for work. To prepare personality tests, pilot candidates should be measured in five main personality areas (agreeableness, extraversion, neuroticism, conscientiousness, and openness) (Wang, Ying, 2018).

If problems are seen in these issues and are not promptly resolved, they may have a significant impact on mental health condition, mission success, and flight safety to a certain extent. Therefore, during the selection tests of the pilot/operator of the UAV, in the evaluation of the psychological state of the pilot candidates; it is necessary to take into account various factors such as a sense of cooperation, emotional stability, high level of conscientiousness, flexibility, responsibility, self-confidence, and achievement orientation (Barnes, Matz, 1998).

The UAV pilot must successfully complete the special training required to be able to control the vehicle by working in an isolated environment to some extent and to ensure the safety of the vehicle. For small UAVs, experience may be less as the operator works in the visual field of view, but for larger UAVs, especially those used in the military or public services, it is important for pilots to have advanced experience for mission success and flight safety (Figure 9) (Chappelle, Swearengen, Goodman, Thompson, 2014).

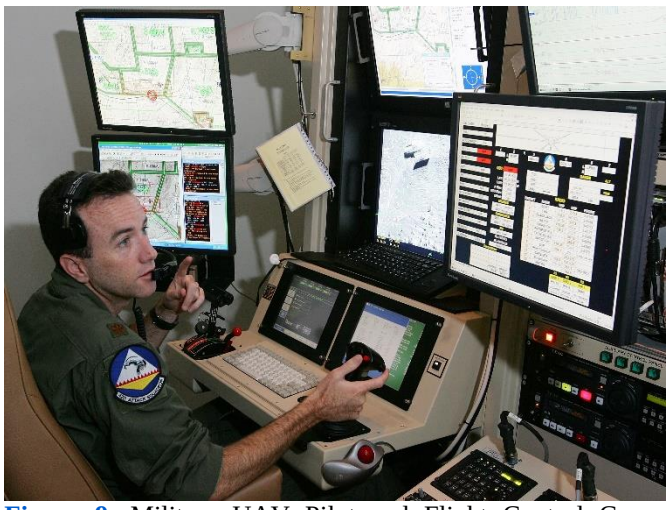


Figure 9. Military UAV Pilot and Flight Control Ground Station

UAV pilots have to know the legislation regarding the use of UAVs, the issues to be applied for a successful operation, and the procedures to be applied for a safe flight during both training and post-training use. It is important that both the physical and psychological state of the UAV pilot meet the flight requirements (Lewis, E. Forster, Whinnery, Webster, 2014).

Comparing with manned aircraft pilot, there is no much physical limitation for UAV pilot and requires lesser operating skills (Ateş, Düzgün, 2020).

UAV is controlled by an expert team including the pilot, data link operator, mission planner, payload operator, and other personnel. This requires more attention to responsibility and while preparing training program. The training of UAV pilots, which have different technological features and are designed for very different tasks, can also be unique. All of this determines that the content and method of UAV pilot training needs to be carefully evaluated on a case-by-case basis (Department of Defense, 2011).

Like manned aircraft pilot training, the UAV pilot needs more training. There are two downsides to relying on UAS program. First one is risk. In manned aircraft, in dangerous situations, the pilot has the opportunity to take some measures to reduce the risk. Conversely, if malfunction occurs during the UAV flight, the most serious consequence will be collision or fall damage. The second is the increasing cost as complexity increases, especially for large UAVs. It will cost more to use real UAVs for each training subject, the need for maintenance, additional safety measures and more crew assistance will be needed. At the same time, wear or damage may occur due to missing controls and misuse, which can increase training, maintenance and operating costs (Wang, Ying, 2018).

The human factor draws attention in accidents that occur during the use of UAVs. Issues related to the human factor consist of four parts. First, from the perspective of the drone pilot, the main impact of the human factor on the task should reveal the limitation of the team in cognitive processes such as situation awareness, attention, decision-making, vision, workload, auditory, and attitude (Ateş, Düzgün, 2020).

Second, the instructor in terms of design and operation; it should be offered ergonomic effects on UAV operation, such as display system, the human- control system, machine interface, and indoor environment in the ground command center. Examining the human error concept major UAV accident research reports and combining them with their experience, the

trainer will be able to analyze how human error affects the operation and propose recommendations and evaluation criteria to prevent human error. Instructor and program developers mainly; should be concerned with analyzing human factor issues that will affect flight safety and operational efficiency, such as situational awareness, human-machine function distribution, and workload (Department of Defense, 2013).

With the inclusion of the human factor in the program, the UAV pilot will be able to demonstrate the importance of the human factor in operations that will reduce disruptions or accidents in UAV operation and increase the safety, reliability and efficiency of the UAV (Uncrewed Aircraft Systems, 2019).

The control of the legal regulations regarding UAVs in Turkey and their implementation, the control of the registration, permit and license procedures of the UAVs used with pilot training and pilots are under the responsibility of the General Directorate of Civil Aviation (GDCA) of the Ministry of Transport, Maritime Affairs and Communications. With the Unmanned Aerial Vehicle Systems Instruction (SHT-UAV) published by GDCA, the procedures and principles of the operations of UAVs in the allocated airspace, relevant organizations and systems, institutions, organizations and businesses that will operate these systems, personnel to be assigned in these organizations, UAV pilots, Procedures and principles regarding air traffic control services to be provided to UAV flight crews and UAVs have been determined (Ateş, Düzgün, 2020).

Within the scope of this instruction; UAVs with a take-off weight of more than 4 kg and a maximum speed of more than 50 km/h, as well as a flight altitude of 100 meters or more from the ground surface, are included. Model airplanes and UAVs produced for indoor use are out of the scope of this instruction (GDCA, 2016).

UAV flights can be performed within the scope of the permission given by DGCA and under the control of a pilot. UAVs that do not require pilot control and can only operate autonomously cannot be used for civilian purposes (Ateş, Düzgün, 2020).

UAV pilots; having additional training from the training institutions and organizations authorized by the DGCA on the use of UAV systems, together with the theoretical training of the relevant Private Pilot License (PPL), successfully completing the UAV pilot training program of the said education institution and being successful in the proficiency check to be made by the DGCA required. UAV Pilot Licenses are issued by the DGCA for a period of 3 years, and if the pilot is re-qualified at the end of this period, the pilot license is renewed (GDCA, 2016).

4. Conclusion

Technological developments in UAVs continue at a dizzying pace, and competition continues at the global level. Since the development and application areas of the UAV have expanded rapidly in recent years, other UAVs, UAVs designed for special missions, manned aircraft, unmanned land vehicles and unmanned underwater vehicles with which it has to work together and act in coordination for the success of the given mission. He has the opportunity to cooperate more with its agents. The UAV pilot needs to be familiar with not only undesirable aircraft conditions and atmospheric conditions, but also the operating procedures of other vehicles, but also must complete systematic training cooperation before the mission is accomplished.

According to statistics and accident investigation reports, the two main factors affecting safety are psychological health and human error. However, there is limited research on UAV pilot training. For this reason, detailed studies on psychological health and human factors are required in UAV pilot training.

All these studies should be reviewed by professional aviation psychologists and included in the training programs and the courses should be determined according to the task characteristics, age and current mental health status.

Considering these factors, UAV pilot training; It should include at the beginning theoretical training, after then simulator training, small UAV operation, and special training that must include almost all training topics, which can reduce the risks and costs of training, to increase productivity, and reduce unwanted damage because of human errors.

As much as UAV technologies improved, military and civil aviation and some other sectors will rely more on UAV. For the drone pilot, the future looks more intense and promising than ever before. Until the safety levels on the UAV reach the levels equivalent to that of manned aircraft, UAV pilots will not be replaced. Now UAV engineers and researchers will provide more contributions to UAV pilot qualification and training program, which may increase the flight safety level and promote the development and application of UAV technologies.

The development of the UAV control system will reduce the workload of the UAV pilot in the future and have more ability in competence. Further research and continuous improvement will contribute to improving UAV pilot qualification and training. In connection with the rapid development and wide application of the UAV, the UAV pilot will play an important role in future aviation.

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