TRAINING MANUAL PROPOSAL FOR UNMANNED AERIAL SYSTEM OPERATORS

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The aim of the article is to present the created training manual for operator of unmanned aerial systems (UAS). It deals with the analysis of the current state in the field of UAV operators' education at the global level. Then theoretical knowledge for operators of unmanned systems with a brief description are summarized. Finally the proposal of the practical training program, structure of which consists of a proposal for practical flight tasks for unmanned aircrafts and unmanned helicopters with brief instructions is presented.

Key words: training manual, operator, unmanned aerial system (UAS), unmanned helicopter.

1 INTRODUCTION

Nowadays the fast development of unmanned aerial systems (UAS) and their arising value not only in the army but as well in the civil sphere causes a need to fulfil deficits, which represents barriers of successful integration UAS into the controlled air space. Success of integration depends on many factors from legislative regulations to technical capability of UAS or personal capability. Aim of the article is connected especially with the capability of staff, who control the unmanned aerial systems.

2 EDUCTIONAL ACTIVITIES FOR UAV OPERATORS IN THE AIRSPACE

Education, training and certification operators of unmanned aircraft systems create an important part of a global integration plan for organization in civil or military sphere.

2.1 Integration of Civil UAS into the National Airspace System

The plan of integration published by a FAA department deals with the secure and efficient integration of UAS into the airspace. Priorities involved in the integration of these systems into the airspace are discussed. The aim is to integrate UAS into the airspace with disrupting existing traffic safety, without threatens airspace users or persons or property and without reducing the existing airspace capacity.

Department collaborates with a wide range of stakeholders from manufacturers, suppliers, trade associations to research and development centres and government agencies and other active members in this field. The study also includes requirements for training programs for operators and crew UAS. UAS training standards will mirror manned aircraft training standards to the maximum possible extent, including appropriate security and vetting requirements, and will account for all rules involved in UAS operation. This may include the pilot, required crew members such as visual observers or launch and recovery specialists, instructors, inspectors, maintenance personnel and air traffic controllers. The FAA´s role in training is to establish policy, guidance, and standards.

Standards for airmen will proceed following the UAS regulation. The FAA will issue UAS airman certificates and support activities to enable UAS operations to include:

- Development of practical test standards and UAS airmen knowledge test question banks;
- Development of a UAS handbook for airmen;
- Training of aviation safety inspectors at the FSDO level to provide practical test oversight;
- Development of a UAS handbook for operator and instructor;
- Development of practical test standards and UAS operator knowledge test question banks;
- Development of UAS mechanic training and certificate process;
- Development of flight crew security requirements by the relevant US Government agencies. [1]

2.2 University of North Dakota

University started has dealt with UAVs since 2009 and now offers a bachelor of science in Aeronautics with a major degree in unmanned aircraft systems operations. The Unmanned aircraft systems operations curriculum is offered to those students whose career objectives are aimed at the civil unmanned aircraft systems industry. The program provides the breadth and depth of instruction needed to ensure graduates are prepared to work as pilots/operators and/or developmental team members of unmanned aircraft systems (UAS) while fully understanding the operational and safety environments of the American National airspace system. Courses require students to be comfortable utilizing complex science, technology, engineering and mathematics principles. In addition, students must possess strong critical thinking and problem-solving skills. A Commercial Pilot Certificate, with instrument and multiengine ratings is required. [2]

2.3 Embry-Riddle Aeronautical University

Since 2011 this university has offered a study program for graduates who wants to be a pilots/operators, observers, sensor operators and operations administrators of unmanned aircraft systems. This degree will provide background in several UAS applications areas, including hazardous operations, surveillance and data collection, secure operations, long duration operations, highly-repetitive operations and autonomous operations. In addition, graduates will be knowledgeable of the engineering aspects of the UAS, as well as the regulatory restrictions governing the operation of UAS in the United States and international airspace. Students entering this program should have a basic background in math and physics. Due to International Traffic in Arms Regulations (ITAR) imposed by the United States State Department, this degree will only be open to U.S. citizens.

There are two tracks available in the Unmanned Aircraft Systems Science Degree. The Pilot Track is designed to prepare the graduate to enter the field as an unmanned aircraft system pilot. While there is a large array of unmanned aircraft available- from insect-sized micro air vehicles to large, airliner-sized turbojets with global capability – pilots graduating from this track will meet all FAA-requirements to operate unmanned aircraft in both restricted airspace and in the public national airspace system.

The UAS Operations Track is designed to prepare the graduate for entry into a variety of non-pilot positions associated with the operation of an unmanned aircraft system. These positions include (but are not limited to) sensor operators, UAS technicians, mission planners, operations managers, and communications support personnel. The graduate will be well-qualified for these positions, receiving training in various operational aspects of unmanned flight, air traffic control requirements, Federal Aviation Regulations and technology relevant to UAS operations. [3]

2.4 Saint Louis University

Cooperation with Prioria Robotics, Inc. of Gainesville, Fla. Results into the launch a research and development program in unmanned systems. This program will lay the foundation for the field of unmanned aerial vehicles (UAVs) both for operators and maintainers. In 2012 they purchased first UAS and UAV simulator that is integrated with SLU’s current Adacel Air Traffic Simulation, allowing CASR to conduct FAA research on unmanned vehicle integration into the national airspace system. Simlat, Ltd. is providing SLU with a full-crew UAS Trainer – a highly advanced UAS training system. CASR will train operational and maintenance crews on unmanned aircraft systems design, maintenance and operations. [4]

2.5 Kansas State University (K-State)

K-State was one of the first two Universities in the U.S., which offers a bachelor of science in unmanned aircraft systems. The program of Department of Aviation of the John D. Odegard School of Aerospace Sciences uses a hands-on approach for learning and attaining the skills needed to safely operate and manage UAS. The Smoky Hills Weapons Range gives students the ability to gain hands-on flight experience. K-State is also one of only a few universities with authorization to fly UAVs in the American National airspace system. The mission of the K-State at Salina Unmanned Aircraft Systems Program Office (UASPO) is to facilitate and promote the safe incorporation of Unmanned Aircraft Systems into the National airspace system above Kansas and beyond. They use their experience in operating, and maintaining aircraft to operate, within the National Airspace System to establish operational guidelines, policies, and procedures and provide for operator training for UASs to fly within the state of Kansas and to ensure the safe realization of the Kansas UAS concept of operations. [5]

2.6 Indiana State University

Indiana State University is one of the first universities too, that offer unmanned systems education and training. The minor program at the Department of Aviation Technology includes an introduction to unmanned systems operations and a study of advanced unmanned aircraft theory. Additional areas of UAS modelling and control fundamentals, ground based systems, visual and electro-optical aspects of navigation, obstacle and terrain avoidance systems, modular on-board processing systems, and current applications are explored. Students learn about the significant regulations impacting the unmanned systems operations and the differences with manned systems. Paramount to all aviation operations, safety assessment, functional requirements, UAS integration, and sensitivity analysis are explored. Students demonstrate proficiency in UAS programming, pre-flight, flight operations, post flight inspection, and mission analysis and debriefing. [6]

2.7 ETH Zürich

Together with the Swiss Federal Institute of Technology (Switzerland) it deals with various aspects of flight control, navigation, trajectory planning, and mission management for UAVs. Originally the main focus was on robust flight control for unmanned helicopters. However, during the last few years we have extended our research activities on flight control for fixed wing aircraft and airships as well as integrated navigation algorithms and computer board developments. [7]

2.8 Recommended Guidance for the Training of Designated Unmanned Aerial Vehicle Operator

The aim of this agreement is to establish a broad set of training guidelines and the skills required of a Designated UAV Operator (DUO) to operate a UAV in all classes of airspace. Participating nations agree to adopt these guidelines, as a basis for the training of DUOs, adapting them where necessary to meet the specialist requirements of UAV type, mission or role. Noting that military operations may require deviation from peacetime rules and regulations, in general, UAV systems shall be operated in accordance with the rules governing the flights of manned aircraft as specified by the appropriate Air Traffic Services (ATS) authority. DUOs must be able to show an equivalent level of compliance with ATS regulations governing training and operational qualifications while UAV systems must meet equipment requirements applicable to the class of airspace within which they intend to operate. Well-trained DUOs and national training requirements to produce them are essential for safe, effective UAV System operations. National authorities must continually refine these training requirements based on the data from evolving UAV system doctrine and operations. Adoption of these operator training requirements by the military services, national aviation certification agencies and the segments of aerospace industry involved in UAV system training and operation will ensure that appropriate safety levels are maintained and public trust in UAV system operations is gained and maintained.

As UAV system operations expand and evolve, data collected and experience gained will aid national aviation authorities in determining the best methods of certifying, controlling and integrating UAV system operations into existing procedures. Operating some UAV systems requires a skill set that approximates that of piloting a manned aircraft. However, there are additional skills that are unique to UAV systems such as relying on synthetic presentations to develop situational awareness. Other differences such as the lack of physical influences such as G-forces that provide performance indicators in manned systems present a unique challenge to DUO.

UAV system control systems vary significantly; some systems use only manual flight controls while others may use a mix of manual and automated, or only automated control modes. Regardless of the type of controls, the DUO must be capable of safely conducting UAV system missions including precise and efficient response to emergency situations. These unique skills are especially critical when operating in conjunction with other manned and unmanned airborne systems.

UAV system training criteria must consider Crew Resource Management (CRM) techniques. CRM is essential for UAV system operations and the DUO must be able to communicate effectively to ensure safety.

Just as pilots of manned aircraft operating in Class G airspace are not required to meet the qualifications required to operate in Class A airspace, the depth of knowledge required of operator will depend on the complexity of the UAV System, mission and the operating environment.

The following topics generally reflect ground-training requirements included:

- Airspace design and operating requirements;
- ATC procedures and rules of the air;
- Aerodynamics, including effects of controls;
- Performance;
- Navigation;
- Meteorology;
- Communication procedures
- Mission preparation. [8]

2.9 Unmanned Aerial Vehicle Aircrew Training Manual

This document published by the Department of the Army Washington, DC describes how important is the cooperation between a units in crew of UAS.

Planning, preflight, and in-flight tasks involve the cooperative effort of all crew members. The prescribed tasks, conditions, standards, and descriptions explain each crew member's responsibility for the successful completion of maneuvers. Each crew member must understand the actions and directives of the other crew members. This enhances crew coordination and unit inter-operability and helps to prevent accidents caused by crew error. The crew coordination descriptions in this publication do not focus exclusively on individual training. They blend an individual training with the collective training.

The training manual includes the following features:

- Commander
- Standardization Instructor Pilot – is the commander´s technical advisor.
- Evaluators – they evaluate, train and provide technical supervision for the UAV standardization program
- Mission commanders – has a responsibility for coordinating all external needs as well as crew coordination.
- Crew member – four types of crew members are the Air Vehicle Operator, External Pilot, Mission Payload Operator and Flight Line Operator. [9][10]

3 OVERVIEW OF THEORETICAL KNOWLEDGE FOR UAV OPERATORS

UAS form a complex that requires interdisciplinary of training manuals. It means that in addition to aerospace engineering and mechanical engineering have to include also electrical engineering, mechatronics or sensor technology. Like all aviation expertise have to include also the knowledge’s of the basics of aerodynamics, engines and other aircraft systems, meteorology, navigation, communications and flight rules. For unmanned systems, it is necessary to have specific knowledge of UAVs, which include telemetry and communication systems and sensor equipment.

The aim of the training manual is to provide the required theoretical training so that the knowledge gained by studying the proposed theoretical knowledge by an operator to carry out practical flight training up to the level necessary competence, which allows him to perform the function operator of a civil UAV.

3.1 Aviation Meteorology

The subject provides an overview of the basic theoretical knowledge from meteorology, ensuring proper knowledge of the principles governing assumption of atmospheric processes in assessing the status and development of the weather. Further it informs students about with issues assessment of the weather condition and prognosis and its impact on the air traffic.

Subject thesis: Atmosphere, wind, thermodynamics, cloud, visibility, precipitation, air masses and fronts, pressure systems, icing, turbulence, thunderstorm, inversion and stratosphere, flying in the mountains, reduced visibility, weather maps, map symbols, pre-flight information. [11][12]

3.2 Air Communication

The subject provides theoretical information in the field of radiotelephones. Operator must have knowledge on the level regarding to requirements and he has to know radiotelephone procedures and air communication phraseology.

Subject thesis: IFR communications, VFR communications, radio-communications, procedures for departure, procedures to track, traffic schemes to departure, loss of connection, emergency and urgent procedure.

3.3 Air Law

Theoretical prepare focuses on the basic of the international air law, knowledge in the field of civil aviation regulations in accordance with the CAA of SR requirements.

Course description: aviation law, operational rules, air traffic regulations and air traffic services.

3.4 Air Traffic Procedures

The subject provides an overview of important principles, requirements and facts contained in the air rules for the organization and conduct of air transport. It also provides theoretical knowledge on the procedures for flights and any other relevant principles important in flight procedures.

Course thesis: air traffic services, area control services, approach control service, airport control service, flight information and emergency service.

3.5 Principles of Flight

Subject thesis: aerodynamics subsonic speeds, speed, flow, resistance, lift and profile, wing and wing airfoils, propeller aerodynamics, horizontal flight, climb, descent and landing maneuvers, stability and maneuverability, flight restrictions. [13][14]

3.6 Air Navigation

Operators in this subject gain information about basic cartographic construction methods used in ICAO aeronautical maps. They will have theoretical basis from air navigation, navigation calculations and explanations of basic terms. The theory is divided into several parts: shape of the Earth, mapping, conformal orthomorphic design, direction, magnetism, maps in practical navigation, basic navigation, instrumental navigation and cartography. [11][12]

3.7 Avionics and Sensor UAV Systems

The theory focuses on general knowledge from avionics and UAV sensor equipment, application equipment and control systems with optimization of flight drones.

Subject thesis: protective UAV systems, navigation systems, electrical systems, communication systems and sensors for application utilization.

3.8 UAV Construction

The subject provides the theoretical knowledge of the UAV airframe structures, airframe systems, power units and definitions of the basic concepts of these areas.

Subject thesis: Airframe structure unmanned aerial aircraft, airframe structure of unmanned helicopter, engine, ignition systems, engines.

3.9 Airports

The subject provides a necessary knowledge for operator to safety use of all the services of airports. Course structure consists of several units that cover all the issue.

Subject thesis: visual navigation aids, visual aids for marking obstacles, emergency and other services and air traffic management aspect.

3.10 Flight Control

The subject provides knowledge about flight control. It is divided into two parts, hardware and software. The hardware part is divided into the on-board control and application equipment of UAV and ground control station, apparatus and functions of controls (primary and secondary effects), the impact on the speed during the flight. The software part covers the program configurations, displaying flight data, camera configurations, control commands, route planning, screening and storage of records, flight simulation.

3.11 Overview of the Recommended Range of Subjects for Theoretical Training of UAS Operators

The minimal range of the theoretical preparation for a successful completion of the proposed training manual consist of 95 lessons applying the methodology of interpretation in a classroom and of working with specialized and scientific literature.

Table 1 Overview of subjects with recommended lessons hours

Subject		Lessons [hours]
3.1	Air navigation	**12**
3.2	Air communication	**8**
3.3	Air law	**7**
3.4	Air traffic procedures	**11**
3.5	Principles of flight	**16**
3.6	Air navigation	**13**
3.7	Avionics and sensor UAV systems	**6**
3.8	UAV construction	**8**
3.9	Airports	**8**
3.10	Flight control	**6**
Completely		**95**

During the theoretical preparation of the UAV operator supplementary methods of self-study and consultation are recommended. After successful completion of the theoretical exercises, the operator is ready to continue with the practical part of the training.

4 PRACTICAL TRAINING PROGRAM

The practical training is tailored by the UAV in a category of MTOW (up to 200 kg) and flight range of more than 80 km. For a successful completion of the training programs, UAS has to include:

- video system with thermal imaging and infrared options;
- sensors systems;
- navigation system and INS;
- ILS landing system and rescue parachute landing system.

Ground control station software of UAS shall provide all necessary flight data on display for the safe control of UAV, including information about UAV:

- position angles;
- climb and descent;
- declination and course;
- altitude, speed, location.

The need of equipment and showing all of flight data's, is coming from basic conditions for training tasks in flying according to N-LOS. Flying according N-LOS (non-line of sight) is a flight where operator does not have direct visual contact with UAV in the airspace.

Practical training manual has 2 separate program parts – for aircrafts and helicopters (or multi-copters).

4.1 Training Program I

It consists of 17 practical tasks aimed at management techniques and basic manoeuvres of unmanned aircraft. After successful passing the training, operator is able to execute secure flights and he is a regular part of flight operation.

4.2 Training Program II

It consists of 14 practical tasks aimed at control techniques and basic maneuvers with unmanned helicopter. The training is proposed to make operator enough prepared for safe execution of flights in opened and directed air space without restrictions for other participants of air traffic.

Table 2 Overview of tasks with recommended number of flights and flight hours for unmanned aircraft

Task	Task content	Number of flights	Flight hours
1	Introducing flight	1	0:30
2	Flight with basic maneuvers	3	1:00
3	Flights to practice simple piloting, slides and flight at min. safe speed	3	1:30
4	Flight to practice estimate of clearance	6	1:00
5	Flight to practice corrections of errors upon landing	5	1:00
6	Flight to practice crosswinds correction	6	3:00
7	Flights to practice turns angled 45°, spirals flights at min. speed and safe emergency landing	4	1:30
8	Flight to practice activities for engine failure	8	1:00
9	Flight to practice turns angled 30-60°, flight at MTOW	5	2:30
10	Flight to practice corners angled 45-60° steep climb with angles up to 30° and horizontal eight	6	2:30
11	Flight in the area of 66 ft to 330 ft GND	4	0:30
12	Instrument flight training to horizontal flight, turns, climb and descent	2	1:00
13	Navigation flights to controlled airports	6	2:30
14	Flight to practice instrument approach and descent to a landing with ILS	2	1:00
15	Flight to practice basic maneuvers at night VFR	2	1:00
16	Navigation flight with using comparative and calculation navigation	5	3:30
17	Program remote control of UAV and application use of on-board equipment of UAV	12	4:00
Σ		**80**	**30**

Table 3 Overview of tasks with recommended number of flights and flight hours for unmanned helicopter

Task	Task content	Number of flights	Flight hours
1	Introducing flight	1	0:30
2	Flight with basic maneuvers, take-off, climb, hover, descent	8	2:00
3	Flight to practice linear horizontal flight, taxi in hover and rotate	6	1:30
4	Flight to practice backwards and sideways	4	2:00
5	Flight to practice horizontal and vertical turns	4	1:00
6	Flight to practice autorotation	5	2:00
7	Flight to practice slope landing	7	1:30
8	Practice flight with max. power take-off and landing with max. deceleration	10	1:30
9	Flight to practice crosswind correction	6	2:00
10	Practice instrument flight	4	1:00
11	Navigation flight to controlled airports	5	2:30
12	Flight to practice basic maneuvers at night in VFR	4	1:00
13	Route flight with using comparative and calculation navigation	4	3:30
14	Program remote control of UAV and application use of on-board equipment of UAV	12	4:00
Σ		**80**	**26**

5 CONCLUSION

Utilization of unmanned systems in recent years has marked a significant improvement of technical solutions, thus creating new opportunities for increasing of efficiency, safety and cost reduction in the air transport. For safe operation of unmanned systems in air traffic it is necessary to ensure a sufficient level of knowledge of all crew members of unmanned systems. The aim of this article was to present the developed draft training manual for operators of unmanned systems. Unmanned systems form a complex that requires interdisciplinary training manuals. This proposal training manual includes theory, which has to reflect knowledge of aircraft pilots. The next part of the training manual consists of practical tasks. Practical training program provides the opportunity to attend training tasks with using unmanned drone airplanes or helicopter.

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