"HENRI COANDA"
AIR FORCE ACADEMY
ROMANIA

"GENERAL M.R. STEFANIK"
ARMED FORCES ACADEMY
SLOVAK REPUBLIC

INTERNATIONAL CONFERENCE of SCIENTIFIC PAPER
AFASES 2013
Brasov, 23-25 May 2013

THOUGHTS ON UAV OPERATOR'S SIMULATOR TRAINING

Lt.Colonel Tamás BALI, Training expert

HDF 86. Szolnok Helicopter Base, Chief of Flight Training, Hungary

Abstract: *It is not unreasonable to say that we are living in the age of the simulator. As a result of the rapid spread of computers and IT systems, simulators have become part of everyday work and life. The world of aviation is no exception. The most developing scope of the modern warfare is relating to the design and deployment of those systems, which - with a minimized casualty number – is capable of fulfilling tactical requirements, reconnaissance tasks, destruction of enemy forces, combat support of own forces and after action evaluations. These requirements are fully covered by the remotely operated vehicles (particularly by the unmanned aerial vehicles). The criterion for the successful deployment is a well-trained system operator. Obviously flight simulators are the essential tools in the operator's training. The objective of writing this article is to introduce flight simulators and outline the perspectives and advantages of their application in the context of UAV operator training.*

Keywords: *UAV -Unmanned Aerial Vehicle., simulator, training, operator.*

PREFACE

The last decade has brought a quite tremendous evolution considering Unmanned Aerial systems (furthermore: UAS) and Unmanned Aerial Vehicles (furthermore: UAV). This evolution can be thanked to the fact, that military leadership has recognized the wide spectrum of possible deployment areas of UAVs upon the asymmetric warfare[1]. As soon as the newly designed UAVs (with their quite new capabilities) got into the military service, the need arose to train operators who can deploy them effectively. Accounting the training devices, which are capable to fulfill the present day's training requirements, we must turn to the simulators. Considering the uniquely short UAS military deployment experience, it is understandable why we have to look at the UAV simulator's market as an improving one.

The immense past deployment experience of UASs revealed that their combat- and combat support capabilities are inevitably important during the modern day's warfare, but their operational effectiveness highly related to the accessibility of a well-trained human resource. Present days we are experiencing the era of a rapid technological evolution, which is practically affects every aspect of our lives. The affects of technological evolution can be traced both in the every day's life, and in the completion of the most complicated industrial processes. The modern technological devices are playing important roles in our activities on ground, in the water and up in the air. All around the world emphasized attention is paid

[1] It is typical during the asymmetric warfare that the participating counterparts warfare's philosophies-, the combat method's in their characteristics are considerably differing from each other.

toward those vehicles which are using the airspace (UAVs included), toward their designs, safe and effective deployment.

Basically, we can divide the UAV connected activities into two main groups. One group deals with the activities related to development, the other one is with the already developed UAV deployment. One of the most effective training mean of preparation to a real UAV application is a simulator[1].

The UAV simulator is basically a training device which is on one hand capable for modeling the elements of the real flying activities under all kind of meteorological situation, on the other hand for modeling the usage of sensors and weaponry. When we are dealing with the real flying elements we must understand all the practical activities from powerplant starting till its shutting down under it. Considering the sensor operator's training, the simulator must be capable for modeling the opposite force itself with its vehicles and ordnance, the enemy's activities/maneuvers with its ground based resources (like radars, air defense systems) under different daytime and concealment circumstances.

UAV OPERATOR'S TRAINING:

It is understandable, that UAV operators must meet high training standards. They must be capable of operating their vehicle, in close cooperation with the related air traffic control units and other air means participating GAT[2] and OAT[3], of effectively using the UAV onboard sensors, of the recognition and quick evaluation of the tactical situation, of proper usage of the ordnance. If we are considering the „capability package" of an UAV, we can form a picture about the UAV simulator requirements/capabilities.

When we are examining the UAV operator's simulators, providing practical training and the capabilities required from them, we must make distinction upon the differences on their deployment fields.

The wide spectrum of deployment possibilities is followed by the range of tasks with their special conditions.

The tactical level battle targets are usually reached by small combatant units (like an infantry platoon), an operational level targets by a combatant force which is not less than a company (rather battalion), and strategic targets by the minimum force of battalion but rather brigades[4]. We can generally declare that the deployment of various UAV categories is determined by the level of the combat targets.

It is understandable that one cannot use the UAV of same category to collect reconnaissance information for an infantry platoon and to explore and destroy enemy's ground-based air defense means.

In order to meet the various operational requirements different categories of UAVs were developed (Table 1.)[2].

[2] General Air Traffic.

[3] Operational Air Traffic.

[4] Regarding the minimal size of the combatant force related to a given strategic level target, we must make an exception with the Special Forces. Special Forces are completing their strategic level tasks basically in an 8-10 soldier group (Special Operational Task Group - SOTG).

Category	**Range** (km)	**Maximum operating altitude** (m)	**Maximum time of flying** (hour)	**Average take off weight** (kg)
Nano	≤1	100	≤1	≤0,025
Micro	10	250	1	≤5
Mini	10	150-300	≤2	≤30
Close range	10-30	3000	2-4	150
Short range	30-70	3000	2-4	150
Medium range	70-200	5000	6-10	1250
Medium range endurance	≥500	8000	10-18	1250

Table 1.: The categories of UAVs.

Evaluating the above demonstrated UAV categories with their given limitations, we can easily declare, that there must be a great difference between the training of an operator using Micro category UAV – who controls his or her device in the vicinity of a clear visual range – and a training of an operator who controls his or her UAV through satellites (since the device has intercontinental level range capabilities). There is no reason to set the same standards toward their training.

SIMULATORS PROVIDING TRAINING CAPABILITIES TO UAVs:

SIMULATORS PROVIDING TRAINING CAPABILITIES TO THE CATEGORIES OF NANO-, MICRO- AND MINI UAVs:

Right before the detailed look into the simulators capable for providing adequate training for the operators of these UAVs, I demonstrate these devices themselves. (Figure 1.)

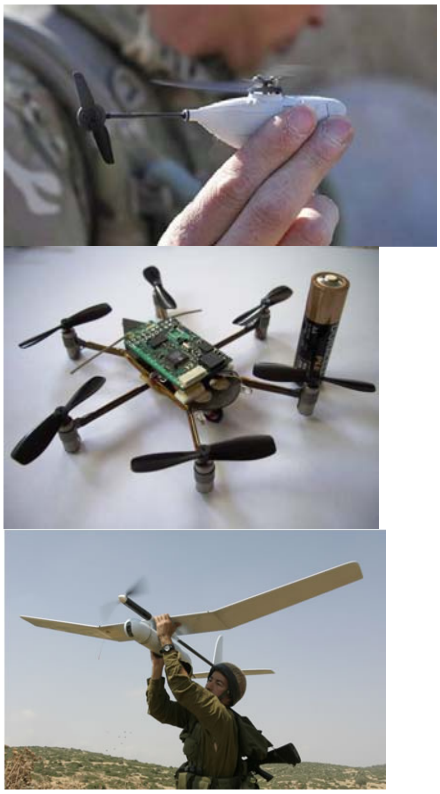

Figure 1.: Nano, Micro and Mini UAVs.

The range of these devices can be considered as a short one, their operational/flying altitude is, usually, low-level. Generally they are deployed in the operators' field of view since radio waves are used to control them. The capabilities provided by them, are basically (solely) limited to reconnaissance data collection. As for their use, they request a crew of two.

One of them is responsible for flying control of the device; another person is a sensor operator who carries out the actual data collection. The two-way communication between them is essential, since the flying route and attitude of the given UAV is closely affected by, and must be continuously adjusted by the online observed location of actual ground based targets.

After these, it can be declared that the deployment of these UAV categories request two main knowledge/skills. One of them refers to the knowledge of flight controlling techniques; another is to the appropriate usage of the on-board sensors.

The device, which provides training for flight control techniques, consists of two structural parts. These are the PC (as a hardware tool) with its installed software that provides UAV visualization in the simulation; and the control devices attached to the PC. The control device's structure is likely the same which is used to control civilian RCs[5]. The sensor operator's training device is connected to a PC providing the main simulation, since there is no reason for operating sensors without the actual simulation itself. (Figure 2.)

Figure 2.: Training device providing simulation for Nano, Micro and Mini category UAVs.

[5] Radio controlled flying devices (models).

Obviously, the operation of the sensors can be only carried out during the actual flights. Could that be a real-, or a simulated flight. As for this, the training for an UAV device operation relating to these categories must be completed in two steps. The flight controller's training must be completed at first, and then the sensor operator's training follows.

It is important to stick to these training steps, since the mission commander can only obtain valuable reconnaissance information if the flight controller is capable to react immediately to the command of the sensor operator. He or she can direct his or her UAV to the best data collection position.

SIMULATORS PROVIDING TRAINING CAPABILITIES TO THE CATEGORIES OF CLOSE-, SHORT- AND MEDIUM UAVs:

Like I did above, I start with the introduction of these kinds of UAV categories. (Figure 3.)

Figure 3.: Close , Short, Medium and Medium Range Endurance UAVs

Since these kinds of UAVs are flown beyond the visual range, both the controlling and navigation are carried out via satellites. The flight route is planned on PC[6] during the pre-flight preparation, and then it is uploaded to the onboard navigational computer. The flight is completed by the operator upon the pre-programmed flight route, keeping his or her device on the given track. Modern medium and higher categories UAVs are installed with such a navigational equipments which facilitates autonomous completion of standard arrival and departure procedures, landings. They are important aids to ease the workload of operators during the long operations, and to lower the flight safety risk.

The tasks of a sensor operator on these UAV categories are not really differing from those, which must be carried out on the lower category ones. The minimum difference is given upon that, the observed information is not transmitted directly to the sensor operator's display via radiowaves, but transmitted via satellites. However, major difference must be observed on the field of onboard ordnance, since medium and higher category UAVs have them on their hard points. These UAVs are capable to demolish both ground located and aerial targets. Because of this, the crew of these given UAVs is complemented with one more person, called weapon operator. The efficient deployment requires complex cooperation among the crewmembers.

After these, it can be declared that the deployment of these UAV categories request three main knowledge/skills. One of them refers to the knowledge of flight controlling and navigational techniques; another is to the appropriate usage of the on-board sensors, the third one is to the use of air-to-ground and air-to-air weapons.

The category related UAV simulator must facilitate the simultaneous training of a minimum two crew member. They are the flight controller and the sensor operator. (Figure 4.)

Figure 4.: Simulator which provides training to a medium category UAV.

The simulator's cabin layout looks exactly the same like the real UAV cabin. The sameness

[6] Personal Computer

can be found in the operator's controls units, in the navigational instrument's displays.

The most important factors of the efficient simulator training are onboard communication and in-flight crew coordination. Only the existence of these, will grant the professional training and operational execution. Once the UAV is flown to the actual target zone the sensor operator takes the mission commander's responsibility. It is him or her, who directs the flight paths of the device by the flight operator, he or she explores the opponent forces, and then he or she makes the target acquisition for the weapon operator. After target acquisition the weapon operator takes mission command. It is him or her, who directs into the best position of weapon deployment, then he or she carries out firing. Following the firing a crucial task must be completed, that is belongs to the sensor operator again. He or she must collect information on the degree of demolition. The evaluation of collected information/data will determine the possible need for repeated actions upon the given targets.

Over viewing the previously explained deployment method, it is clear that the success of a mission depends closely on the efficient communication among the crew members. As for this, both the simulation and the "real UAV" cabin layout facilitate the work of crewmembers in a common space. They are not separated from each other or confined to a separate work in separate rooms. But there is one more advantage of a common cabin work, it makes possible for them to look over to each other's displays. It is useful, if we consider that the well-trained crewmembers can prepare for the next tasks which are implied by the images. For instance the flight controller can direct the UAV to the best observation position prior the sensor operator's command.

THE REQUESTED CAPABILITIES UPON UAV SIMULATORS, PROVIDING PRACTICAL TRAINING:

There are clearly set requirements toward the simulators, which are providing practical training aid for the various operators. However these requirements have been set upon a quite short operational experience. Firstly, we have to declare that useful practical training can only be completed on a simulator which "flying" characteristics are the same like the real devices'. If the simulation cannot meet the aerodynamic requirements, the flight controller/operator – after his or her training – won't be able to carry out safe flights. Should an unexpected weather phenomenon emerge during the given flight, the operator will loose his or her control over the UAV, which lead to the damage of a device.

Controls, used by flight controller, sensor and weapon operators must be totally the same like those, which are installed into the real UAV device. It is crucial and required, since during a real time missions it is common to carry out sudden control movements[7]. In these cases, the efficient and safe deployment depends on automatic reactions/control movements of the operator, which were created in the simulator.

The simulator must possess an interface, which facilitates the adjustment of weather criteria/setting preflight and during the actual flight. The possibility of weather setting adjustment is important for practicing various flight maneuvers under different circumstances (underlining take off and landing procedures). The option of changing meteorological situation in the simulation is useful (especially at short and higher-categories UAVs), when the flying time between taking off and landing is so long that a change in the meteorological conditions is presumed It could happen, that at the time of taking off the weather conditions can be considered as simple, but at the time of landing it deteriorates because of a possible sandstorm. This means that - as an essential requirement - the simulator device's software must support setting changes regarding to wind direction and speed on different altitudes, changes to precipitation (conditions like: fog, rain, snow, ice), settings on various types of clouds on their coverage rates on different altitudes.

[7] Immediate action is necessary from the controller if the flight equilibrium is affected by the weather elements, or to avoid obstacles during low-level flights. Immediate intervention is required from the sensor operator, if enemy forces and equipment popping up suddenly at the periphery of his or her surveillance zone.

The simulator must support both daytime and night time flight circumstances. For the full flight daytime training, the simulation must be able to realistically display natural/terrain (hills, mountains, trees)-, and artificial (buildings, towers) obstacles. Furthermore, in the context of contemporary operations, it is stated that the need arose to display combat forces applied at night. Since the development of sensors increasingly shifting UAV deployment toward the direction of the night, it is important to underline the night flight simulation.

The simulated spatial visualization must support the fulfillment of basic flight elements such as straight and level flight, climb and descent, constant angular-speed standard turning, turning to specified direction, climb and descend turns with different steeps, configuration changes, airport visual approach procedures.

Especially in the first phases of flight training, there is almost constant danger that the UAV gets into an "in-flight adverse attitude"[8]. In order to be exercised in the management of these complex situations, spatial visualization must be capable to support the completion of large-pitches, steep turns, and flying at stall speed.

At short and higher categories of UAVs, the simulation must provide the possibility to install navigation information to the on-board PC, considering the VFR[9] and IFR[10] flights. It is important that these navigational procedures can be even completed in the simulation. For the training of IFR navigation procedures, the simulation must include the ground-based (simulated operating) navigation equipments (VOR[11], ILS[12], DME[13], NDB[14]). Since the satellite navigation system (GPS[15]) is an indispensable tool for these category UAVs, the simulation must be able to support GPS navigation.

The UAVs are an integral part of a general aviation. They are flying in such a dense airspaces, which are regulated by restrictions; the usage is precisely coordinated/managed by air traffic controllers. Therefore, UAV operators must know and understand GAT in general; how the structure of the airspace is formed, what are the basic rules on airspaces usage; how to coordinate with the airspace management units; how to forward different airspace request orders. Therefore, the simulation must ensure the setting of air traffic flow, and the generation of air traffic control.

Beyond the exercises of practical flight elements it is important to master the application of the sensors, as well. Modern UAVs primarily have electro-optical and infrared reconnaissance tools. Electro-optical sensors are used for the daytime observations, while night vision capable sensors (working in infrared range) for information gathering during night time. In order to ensure that received signals can be utilized by the sensor operator, the software of the simulation must support the realistic imaging. Accordingly, the simulation must ensure both day- and night time target visualization on the enemy forces and on their weapons.

The simulation of enemy activity is closely related to sensor operator's training. . In a view of UAV's tasks, the simulation visualization must primarily focus on the enemy forces,

8 The in-flight adverse attitude means that the device is (accidentally) forced to the flying attitude which differs basically from the safe/normal, and poses fight safety risk toward GAT, OAT. The risk of crash is imminent.
9 VFR = Visual Flight Rules.
10 IFR = Instrument Flight Rules.
11 VOR = VHF Omni-directional Radio-range.
12 ILS = Instrument Landing System.
13 DME = Distance Measuring Equipment.
14 NDB = Non Directional Beacon.
15 GPS = Global Positioning System.

on their maneuvers, on the enemy's ground-based weapon systems (e.g. radars, air defense complexes). The simulation must be capable to model the activities of low-level- and speed flying aircrafts, as well as airspace violator fighters. The sensor operator – during his or her training – must detect enemy's activity; identify all of the natural and artificial obstacles which could affect the freedom of movement of our own forces. He or she must be capable of an accurate data evaluation, and of a speedy processing. This implies that simply the sensor management training is not enough for a well-trained operator. It is important to learn the tactical knowledge as well.

At present time, it is normal to have (especially on close- and higher category UAVs) weapons hard points. Considering the weapons, the air-to-air and air-to-ground missiles are used. There are numerous simulation criteria for an efficient weapon operator's training. One of them is a proper day and night visualization of enemy forces (explained above), another one is a real visualization of the given weapon's destructive impacts. The simulator's hardware system must include that weapon control panel, with its design and usability, which must be equal to the "live" device's control panel. The weapon operator's training can only be considered as effective, if the weapon operation reach the proper level of destruction. The assessment of the extent of the destruction is such an important question, which must be answered in the simulation.

In the case of training for multiple crew UAV operations (flight controller, sensor and weapon operator), the first step always must be the crew position specialized, customized training. After this individual training - in order to form proper crew co-operation - the crew level training takes place. The training for the crew's proper onboard co-operation, in NATO terminology, is called to be "Crew Resource Management" training (CRM training). In order to facilitate CRM training, simulation must support the crew level pre-flight preparation, a common platform task execution (with the simulation of on-board communication, rapid information exchange) and post-flight evaluation.

In relation to the requirements set toward UAV simulators I have only been writing about the training means of operators, but it is important to mention the so-called "Instructor facility".

The Instructor facility must facilitate the adjustment of pre-flight and in-flight meteorological situation; the tactical situation even during the execution; the maneuvers of the enemy forces; the air traffic situation. It must be capable to imitate aircraft failures during the entire flight (from engine start up till its shutting off). During the execution of the given task, in order to have operators' experience in detecting and managing certain instruments, and system failures gained, the Instructor facility must simulate any kind of failures, at any stage of the flight.

Accordingly, the Instructor facility must be able to: set meteorological conditions, imitate failures, adjust visual background during VFR and IFR flights, load navigation data, and simulate communication between air traffic control units and other aircrafts.

SUMMARY:

The object of writing this article was to explore the possibilities of flight simulators used to aid UAV operator's training, to introduce current simulators with their capabilities, limitations, and their possible application areas. I tried to summarize all the expectations toward the UAV simulators which have been my collected upon my pilot training experiences.

Upon my expectations I corroborated that one of the most important and most cost-effective element of the UAV practical training lies in the simulation, their usage is essential to the application of an aircraft with complex systems. Training on them, regarding the flight safety aspects, is inescapable in the period of combat training phase.

The subject , which is evaluated in the followings, was realized through the assistance of the European Union, with the co-financing of the European Social Fund. "Critical Infrastructure Protection Research TÁMOP-4.2.1.B-11/2/KMR-2011-0001".

Subordinated plan: „Data integration. Highlighted project: „Operations of Unmanned Aerial Vehicle and its aspects for Air Safety"

REFERENCES:

[1] Dr. Kevin Heffner - Dr. J. Mark Pullen: Effective Simulation Support for Operator Training and Experimentation in Unmanned Aircraft Systems Development and Deployment, Downloaded: http://ftp.rta.nato.int/public/, 05 february 2013 21.14;

[2] Dr. Dudás - Dr. Restás: Nemzetközi példák az UAV repülés emberi tényezőit érintő jogi szabályozásra az RPAS 2012 konferencia tapasztalatai alapján (Repüléstudományi közlemények, XXIV series 2012 3. issue, ISSN: HU ISSN 1789-770X);

[3] Charlotte Adams: Simulation and Training (Rotor & Wing magazine, Rockville /USA/ june 2010, p 24-30, ISSN-1066-8098);

[4] Carl Nehme, Jacob Crandall, Mary Cummings, "An Operator Function Taxonomy for Unmanned Aerial Vehicle Missions", Downloaded: http://hdl.handle.net/1721.1/55960, 05 february 2013, 21.30;

[5] United States Army UAS Center of Excellence, "Eyes of the Army - US Army Unmanned Aircraft Systems Roadmap 2010-2035", Downloaded: http://www.ausa.org/publications/ilw/Documents/TB-US%20Army%20Unmanned.pdf, 09 march 2013, 20.00;

[6] NATO STANAG 4670 Edition 1, NATO Standardization Agency, 28 april 2009;

LIST OF FIGURE'S HYPERLINKS:

Figure	**Hyperlinks**	**Remark**
1.	http://images.gizmag.com/hero/black-hornet-nano-uav.jpg http://static.rcgroups.com/forums/attachments/2/1/9/7/5/0/a2542518-238-Spektrum%20Version.jpg?d=1243225300 http://defense-update.com/images/New_Skylark.jpg	Downloaded: 17 march 2013, 20.15 - 22.00
2.	http://uavdronesforsale.com/index.php?page=item&id=24	Downloaded: 17 march 2013, 21.47

Figure	Hyperlinks	Remark
3.	http://www.armybase.us/wp-content/uploads/2009/04/boeings-scaneagle-uav-drone2.jpg http://www.airforce-technology.com/projects/rq5a-hunter-uav/images/hunter_4.jpg http://media.defenceindustrydaily.com/images/AIR_UAV_Watchkeeper_Landing_Thales-UK_lg.jpg http://dronewarsuk.files.wordpress.com/2012/05/drone.jpg	Downloaded: 17 march 2013, 20.00 - 22.30
4.	http://defense-update.com/images_new/PMATS_GCS_Predator_Sim_L3.jpg	Downloaded: 17 march 2013, 21.30