OPERATIONAL AND TECHNOLOGICAL DIRECTIONS FOR UNMANNED AIRCRAFT SYSTEMS DEVELOPMENT

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Abstract

Unmanned Aircraft Systems are continuously delivering new and enhanced battlefield capabilities to the military sphere. While the demand for unmanned systems remains at a relatively high level, it is expected that a number of operational and technological factors will further influence unmanned program development in the nearest future. The purpose of this paper is to articulate a vision for the continued development of unmanned systems technology across military applications. This article establishes a technological and an operational vision for the next 25 years and outlines actions and technologies for military experts and industry to pursue to efficiently align with this vision.

Keywords: *Unmanned Aerial System, Unmanned Aerial Vehicle, Autonomy*

Introduction

Unmanned Aircraft Systems – UAS (Joint Doctrine Note 3/10 2010 p.1-2)[1] have become the key elements determining proper task execution both in the military

1 Unmanned Aircraft System – UAS refers to Unmanned Aerial Vehicles – UAVs and supporting components as a whole. In other words, the system comprises UAVs, necessary equipment, data distribution, as well as the supervising personnel. Ministry of Defense, 2010. *Joint Doctrine Note 3/10, Unmanned Aircraft Systems: Terminology, Definitions and Classification,* p. 1-2. The Development, Concepts and Doctrine Centre, Ministry of Defense, Swindon.

and civilian field. Over the last decade, the demand for such systems has grown significantly, which in turn, has created new challenges, such as the need for integration with other systems in use. The present article aims at determining the functional and technical conditions for the development of Unmanned Aircraft Systems. The author intends to answer the following questions: *What are the directions of operational development of the Unmanned Aircraft Systems and what are the directions of technological development of the Unmanned Aircraft Systems?*

Research in the source literature (ed. Zajas 2009)[2] has been a useful tool in predicting changes in the use of Unmanned Aircraft Systems in the contemporary battlefield. Additionally, the directions of the technical development of UAS have been analysed and the anticipated scale of UAS development has been assessed. The article, however, focuses exclusively on the types of UAS dedicated for military purposes. Therefore, the types of UAS which, due to their small range and size or short flight time are not used by the military, have not been analysed.

Directions of functional development of Unmanned Aircraft Systems

On the basis of the analysis of the source literature, it can be assumed that the contemporary use of Unmanned Aircraft Systems is restricted to Intelligence, Surveillance and Reconnaissance – ISR tasks and Air Attack tasks. Such a UAS function results from the direction they have developed so far and the way they have been used in the contemporary battlefield (Office of the Secretary of Defense 2014, p. 85). Taking into account long-term research plans regarding UAS carried out in the USA and West European countries, we can anticipate a significant growth in the combat use of such systems.

According to *Unmanned System Integrated Roadmap FY2013-2038* (Office of the Secretary of Defense 2014), the research into Unmanned Aerial Vehicles designed

2 Further information can be found in the following documents: The Joint Air Power Competence Centre (2010), Office of the Secretary of Defense (2014), US Military Academy (2016), U.S. Air Force (2009).

to be used in combat, ISR and airlift missions may be carried out in the following 20-25 years (US Military Academy 2016). Nevertheless, it should be pointed out that as far as the aforementioned tasks are considered, there is an overall tendency to wait for an increase of autonomy and the development of so called artificial intelligence that could increase the possibility of using UAVs to execute more complicated tasks (Kuptel and Williams 2014).

The philosophy of using UAVs to execute Intelligence, Surveillance and Reconnaissance tasks adopted by the USA and a number of Western countries is aimed at the development and introduction of UAS prepared to execute Stand-off, Overflight and Anti Access Area Denial – A2/AD tasks (Office of the Secretary of Defense 2014).

It is expected that increased flight time of UAVs, combined with high reconnaissance altitude will ensure apt conditions for the use of on-board technical reconnaissance equipment and provide a wide detection and identification range. This will allow UAVs to conduct ISR tasks in peacetime, without the necessity to violate the enemy's airspace. In crisis and wartime, the possibility to conduct Stand-off ISR will, in turn, increase the endurance of unmanned platforms.

Perspective operational concepts concerning various ISR tasks anticipate the use of UAVs in tasks requiring direct flight over the reconnaissance target. The concept of the US Department of Defense implies the future possibility of using UAVs to monitor maritime areas and execute ISR tasks during peacekeeping and anti-terrorist operations. The main requirement for ISR missions, including direct flight over the reconnaissance target, is the ability to suppress the enemy's Surface Based Air Defence system to an extent sufficient to ensure the safety of the platforms. It is worth mentioning that flights over the targets are planned to be conducted at a medium altitude where UAVs are susceptible to turbulence and icing.

American and West-European plans clearly emphasise the need to develop specialised UAVs optimised to conduct ISR tasks requiring the penetration of well protected airspace. In the future, specialised UAVs should be able to execute ISR tasks in a way and time not predicted by the enemy, by entering its territory without prior warning (Defence Science Board 2004 quoted in U.S. Air Force, 2005). The use of UAS will eliminate potential complications caused by shooting off the plane, losing the crew or using the crew in order to spread propaganda.

At present, the extent of fire missions executed by Air Force UAVs is restricted to armed reconnaissance while maintaining air superiority. Relatively light equipment limits the UAVs ability to attack multiple or technologically advanced objects.

Perspective concepts regarding the use of UAVs in combat missions are based on two possible development scenarios (Duck and Summer 2012). Firstly, preparing UAVs to conduct air strikes. Secondly, developing specialised Unmanned Combat Aerial Vehicles - UCAVs capable of using special reconnaissance sensors. It is expected that in the coming years, the use of UAVs should bring some significant benefits in comparison to the execution of such tasks by manned aircraft. Numerous studies emphasise that the main benefit of the solution will be the elimination of the risk of air crew loss. Another advantage seems to be the possibility of improving UAVs endurance by limiting effective reflecting surface and decreasing theamount of thermal and acoustic data, as well as the ability to execute maneuvers with overload exceeding the body's resistance. According to American concepts, fire missions are divided into two main groups: Strike, Persistent Strike, Armed Reconnaissance Missions and Suppression of Enemy Air Defences – SEAD.

Air strikes are to be executed while maintaining air superiority and, additionally, in case there is a need to attack targets located in the deep battle area where the enemy maintains air superiority. Therefore, it is assumed that whenever UAVs tasks are executed in airspace dominated by one's own forces, persistent strike combined with armed reconnaissance will be conducted. Moreover, it should be emphasised that at present, such operational capabilities are being implemented in the US Unmanned Aircraft Systems on a limited scale and that they indicate the direction of development of UAVs for the next few years.

Reaching the UAVs capability to attack well protected sites is a perspective aim as far as the increase in the number of tasks carried out by Unmanned Aircraft Systems is considered. It is expected that in several years or so, various types of specialised UAVs, optimised to execute tasks in the deep battle area, will be introduced in numerous countries. Additionally, it is assumed that due to their endurance, higher than that of manned aircraft, UAVs will constitute a major type of equipment used to attack well protected sites and, consequently, will often be able to substitute manned aircraft in such missions.

Directions of technological development of Unmanned Aircraft Systems

Tendencies in the field of the technological development of UAVs may be analysed with regard to particular elements of construction and equipment such as: airframe, propulsion systems, avionics and specialised equipment. This will allow the identification of technological solutions that, in a few years perspective, will become major aspects of UAS technological development.

It may be assumed that over the next 15-20 years, characteristic dichotomy regarding UAVs airframe construction will persist. Taking into consideration the targeted UAV environment as well as the diversity of tasks carried out by various classes and types of UAVs, two basic construction solutions may be predicted. In the case of UAVs optimised to execute tasks in their own airspace or to be used in the operational area where air superiority is maintained by one's own forces, the need to provide maximum flight length at medium and high altitudes as well as the possibility to transport a relatively large useful load will be the main decisive factor concerning the airframe. Much lower construction requirements concerning the aforementioned group of unmanned systems will apply to airframe resistance to work overload and UAVs maneuvering abilities. Taking into consideration the solutions used in the construction of the airframe for specialised unmanned systems combat designed to conduct air strikes against the enemy's modern air defence assets or well protected sites located in the deep battle area, an entirely different approach towards the requirements regarding the airframe can be noted. Furthermore, in view of the solutions used in UCAVs, we can observe an overall tendency to use aerodynamic systems that increase the construction resistance and decrease the reflection area in radar frequency and thermal bands.

Currently, the size and weight of UAVs airframe are about 20-30% (Carlson 2001, pp. 29-30) smaller than their manned counterparts. Therefore, it can be estimated that due to technological advances in the field of miniaturisation of air weapon systems and improvement of propulsion systems efficiency, new generations of UAV airframes may be about 30-50% smaller and lighter than their equivalents used in manned aircraft systems. Optimisation of UAVs airframe will take into consideration their resistance to work overload, significantly bigger compared to manned aircraft.

In view of the American experience (e.g. derived from *J-UCAS* program), we may expect the first generation of UCAVs airframes to be resistant to work overload of about 3 to 20 G. Depending on the size of the airframe, the numbers may remain the same within a given time frame or they may change slightly for smaller sized UAVs. It is anticipated that the UAV airframes construction process will most likely involve the use of carbon composites. As a result, the ratio of airframe weight to UAVs total weight will be more advantageous. Nevertheless, we may predict that due to the complexity of carbon composite UAVs repairs as well as fast propagation of construction damage, it will be necessary to find materials that could substitute or at least complement such composites. It is highly possible that UAV airframes will soon be made of enhanced carbon composites able to self-repair relatively small damage caused by enemy fire (Office of the Secretary of Defense 2014). The materials are intended to be used in UAVs designed to execute long-haul flights.

In a few years perspective, the possibility of using transgenic biopolymers in the construction of UAV airframes cannot be excluded. The material is about 25% lighter than carbon composites, but at the same time, it is flexible and its strain resistance compared to steel is twice as high. Studies included in *Unmanned Systems Integrated Roadmap 2013 – 2038* indicate that due to the aforementioned qualities, transgenic polymers could be widely used in the process of UAV airframe production, thus making it possible to reduce the construction weight and increase its endurance at the same time (Office of the Secretary of Defense 2014, p. 77).

It is possible that in the next twenty years or so, along with aerodynes, UAVs will be equipped with aerostats. The situation is due to recently intensified efforts to create unmanned systems able to operate in the atmosphere at very high altitudes described as near space altitudes[3]. Due to the fact that traditional airframes would need a vast bearing surface to generate enough lift at such altitudes, use of aerostats is considered to be one of a few possible ways of conducting flights at near space altitudes.

Adopting such a philosophy of building UAVs should allow them to execute flights for a few or several days at altitudes above the range of contemporary Surface Air Missiles and ensure continuous execution of tasks in particular areas (USAF Scientific Advisory Board). One of the benefits of using aerostats as UAV airframes will be the possibility of providing a considerably longer flight time and higher flight altitude compared to the current performance. Unmanned aerostats will thus be able to take over some tasks of satellite systems, execute them at a lower cost and remain in certain operational areas all the time. A study prepared by the American Scientific Advisory Board entitled *Persistence at Near Space Altitudes* concludes that despite their, much bigger than that of aerodynes, capability of executing flights at high altitudes, aerostats will be less useful than traditional, widely used aircraft constructions. The conclusion results from the fact that aerostats are highly prone to certain weather conditions, especially wind (USAF Scientific Advisory Board).

The analysis of contemporary and perspective technical solutions planned to be used in UAS indicates that, apart from the airframe construction, the usefulness of propulsion systems will have to be reassessed. As a result, we may expect a wider range of more efficient propulsion systems to be introduced in contemporarily used UAVs. In addition to traditional reciprocating, turbine and turbojet engines that have been used in UAVs so far, electric propulsion, fuel cells and solar panels as well as combinations of the abovementioned elements as a part of a hybrid drive can be used on a larger scale. Similarly to the development tendencies in the field of airframes, the requirements concerning propulsion systems for UAVs

3 In English-language source literature, the area is described as “near space” and defined as altitudes between 65 000 feet and 325 000 feet, which, in other words, relates to altitudes above the highest ones used by contemporary aircraft and below the lowest satellite orbits.

designed to operate in the deep battle area will be much different from those for propulsion systems used in UAVs operating in a relatively safe environment.

Contemporary research concerning UAV propulsion systems planned to be introduced and used in a dozen years or so indicates that, as far as turbojet engines are concerned, there is a dominating tendency to increase engine thrust while reducing fuel consumption and engine weight. The *Integrated High Performance Turbine Engine Technology (IHPTET)* programme conducted by DARPA, NASA and the US Army succeeded in widening the tactical range by 35% and increasing the length of UAV duty shift by 120% only by having implemented optimisation solutions promoted in the programme. The research was conducted in order to compare the possibilities offered by IHPTET technology to the newest serial solutions used in the Honeywell F 124 engine designed for the Boeing X-45 A UCAV Demonstrator. The programme is being continued in the form of current project work entitled *Versatile Affordable Advanced Turbine Engines (VAATE)* and *ADaptive Versatile ENgine Technology (or ADVENT)* programmes aimed at reducing the costs of turbojet engine production. The ultimate objective is the improvement of engine reliability, simplification of its construction and fuel consumption reduction. (Office of the Secretary of Defense 2014).

Over the next few years, turbine engines designed for UAVs are to be used in UAVs with a maximum take-off mass below 1000 kilograms. Turbine engines, both two-stroke and four-stroke ones, currently used in UAS, fulfil most requirements regarding fuel consumption, reliability and weight-to-power ratio. Therefore, the process of improving turbine engines designed for UAVs lighter than 1000 kilograms will focus on adapting them for the use of JP aviation fuel (e.g. JP5 or JP8) or diesel fuel, so as to harmonise various types of fuel in the logistic support system.

Fuel cells and solar cells are not currently considered the main propulsion type for UAVs. At the beginning of the 21st century, NASA conducted research on the use of fuel cells in hydrogen gas technology for Helios UAV, which proved that the efficiency of such a type of propulsion for a two-stroke engine was around 80% (500 Watt/h/kg compared to 600 Watt/h/kg). It is expected that the improvement of hydrogen gas based fuel cell technology combined with solar batteries may lead to the creation of propulsion designed for UAVs executing enduring tasks at high altitudes. Therefore, it may be assumed that the abovementioned types of hybrid propulsion may be introduced in the nearest future, thus giving UAVs operating at near space altitudes the possibility to fly for a few weeks or even longer with the use of solar energy in daytime and fuel cell energy at night. However, a much more likely solution seems to be equipping traditional, turbojet, turbine and reciprocating UAV engines with solar and fuel cells generating additional energy for on-board electronic systems.

The improvement of already functioning technologies used in UAVs on-board reconnaissance equipment as well as the implementation of new technologies are important aspects of the technical and technological development of UAS. On the basis of analysis of the solutions currently used in UAVs, it can be concluded that technical reconnaissance systems used by UAS consist of three main groups (UAS 2006):

- *optoelectronic reconnaissance systems,*
- *radar reconnaissance systems,*
- *electronic reconnaissance systems.*

It should be noted, that current optoelectronic reconnaissance technologies are not developed separately for manned and unmanned platforms. Hence, the same systems and solutions are installed on manned and unmanned platforms. It may be anticipated that in the following years, optoelectronic reconnaissance devices will remain an important part of UAV equipment, mainly due to the passivity of detection techniques and accuracy of the data provided. However, we may also predict that specialised military systems will gradually replace commercial solutions used in UAV on-board reconnaissance systems.

An example of such a system is the optoelectronic Advanced EO/IR UA Sensor with an increased range, enhanced picture stabilisation and widened observation area in comparison to previous, currently used generations of optoelectronic equipment installed in UAVs. Another widely used type of equipment are radar reconnaissance systems based on synthetic aperture radar imagery enabling a resolution of approximately 30 centimetres. Ground Moving Target Indicators – GMTI are also commonly used nowadays. In view of the analysis of the solutions that are being implemented in UAS, it should be noted that the coming years will bring automatic correlation of data obtained by on-board optoelectronic and radar systems resulting in an integrated imagery. With these changes, the UAVs resistance to delusion and camouflage will undoubtedly increase. Taking into consideration tactical and technical capacities of currently manufactured UAV radar reconnaissance systems, we can assume that they are going to be improved by increasing imagery resolution and resistance to disturbances as well as lowering the equipment weight. The precursors of such devices may be LYNX - the American radar tested on Hunter UAV, with a resolution of 10 centimetres and SAR/GMTI functions and an approximate weight of 27 kilograms (63 lbs) and MISAR – the radar manufactured by EADS company for German UAVs LUNA, weighing 4,5 kilograms. (Office of the Secretary of Defense 2014). In the longer perspective, it is expected that the range of technical reconnaissance systems used in UAS will increase. Among numerous detection techniques that can be used in UAVs on-board reconnaissance equipment, the most promising are:

- *Multispectral and Hyperspectral Imagery – MSI / HIS*
- *Synthetic Aperture Radar enhancements*
- *UHF / VHF Foliage Penetration (FOPEN) Synthetic Aperture Radar*
- *Light Detection and Ranging (LIDAR) Foliage Penetration*
- *LIDAR imaging*
- *LIDAR aerosol illumination*

The use of on-board multispectral and hyperspectral imagery will allow effective detection of camouflaged objects and identification of horizontal objects, including the ones located in the foliage. Thanks to the reconnaissance being conducted simultaneously in several dozen (multispectral) and several hundred (hyperspectral) optical visible light and infrared radiation frequency bands, the credibility and accuracy of imagery data should increase. At present, initial research is being conducted on the use of multispectral and hyperspectral imagery in the operation of US UAVs.

The TALON RADIANCE research programme examined the possibilities of detecting tanks camouflaged in foliage and, as a result, the Infrared Remote Imaging Transition Testbed (SPIRITT) is to be installed on Global Hawk and MQ-9 Reaper UAVs. The possibilities of using multispectral and hyperspectral imagery in UAVs on a large scale are now limited by the lack of databases and algorithms allowing identification of objects detected in the battlefield in varied weather conditions with a various amount of light. Therefore, building multispectral and hyperspectral sensors seems to be much more feasible than producing on-board data processing systems.

It is expected that in the next few several years or so, further development of the synthetic aperture radar (SAR) technology may bring some quality changes in the ways air reconnaissance is conducted by UAS. Due to increasing requirements concerning imagery data accuracy, it is expected that on-board UAV radars will be able to provide more precise, accurate and frequent data regarding dislocation of targets on the battlefield in close to real-time. Taking into consideration the limited possibilities of storing and processing data in UAV electronic systems necessary to ensure *Coherent Change Detection- CCD,* we may expect that not all UAV types will be able to perform such functions (Tom 2002).

Available information sources regarding the development of SAR technology for UAS imply that in the next few years, it will be possible to use electric beam guidance in order to increase the range of UAV on-board radar systems. Under the US *Multi-Platform Radar Technology Insertion Program (MP – RTIP),* active electronically scanned antennas – AESA are currently being tested. Additionally, there are plans to equip Global Hawk UAVs with such antennas that will give them not only the possibility to provide radar imagery of the battlefield but also to detect the enemy's air interdiction assets.

Intensive research on the possibilities of UHF/VHF Foliage Penetration by UAS has been carried out for a few years. In 1997-2003, DARPA, in cooperation with the Army and the Air Force, conducted research that resulted in the construction of the UHF/VHF radar that is currently being used in the RC-12 government UAV and in the Global Hawk UAV (Moyer 2002). At present, under the *Wide-Area All-Terrain Change Indication and Tomography (WATCH-IT)* programme, the UHF/VHF radar is being enhanced in order to enable UAS to detect objects located in urban areas. The possibility to send imagery data directly from UAVs to the Air Force headquarters and manned aircraft is an important aspect of the UHF/VHF imagery that will significantly increase the Air Force ability to fight mobile objects and create new demands regarding UHF / VHF Foliage Penetration systems.

It is worth mentioning that LIDAR imaging may be used in military UAS in a similar way. However, due to the fact that research on LIDAR technologies is only in its initial phase, the current efficiency of such type of imaging is worse than optoelectronic and synthetic aperture radar imagery. Owing to advanced technologies of processing laser beams bouncing off detected objects, LIDAR should allow penetration of the area covered by foliage. The penetration should be possible even in difficult conditions such as cloudiness and limited visibility resulting from dust or air congestion. An important advantage of LIDAR imaging is its distance measuring accuracy of about a few centimetres, which would give the UAVs equipped with LIDAR imaging systems the possibility to precisely locate targeted objects in urban areas or forests. In the coming years, LIDAR imaging systems installed in UAVs may be used to detect clouds of poisonous chemicals or biohazardous substances floating in the air (Office of the Secretary of Defense 2014). This important function, combined with hyperspectral imagery, will allow fast detection of symptoms suggesting the use of chemical or biological weapons and consequently reduce the time needed to alert the military and civilians.

To sum up, UAV reconnaissance systems will mainly use optoelectronic and radar detection techniques in forthcoming years which may be supported by hyperspectral and LIDAR imagery. A significant advancement in comparison to currently used technical imagery systems will be the possibility of processing imagery data into coherent imagery on board UAVs in close to-real time and instant distribution of data to recipients.

Further development of UAS tasks will generate a serious increase in demands concerning communication systems. As far as UAS are concerned, it will still be necessary to exchange information via data links in order to provide flight control and execute combat tasks by ground surveillance systems. It may be predicted that in the next several years or so, digital imagery data transmission in the form of video sequences from UAVs to Tactical Command (TACOM) and combat aircraft will become a standard procedure. In the event of a simultaneous use of more than one technical reconnaissance system in one UAV, data transfer will be very high and may even exceed 274 Mb/s. However, sending SAR and hyperspectral imagery data to ground terminals in close to-real time constitutes a serious challenge for communication systems. Studies by American specialists in *Unmanned Systems Integrated Roadmap 2013 – 2038* indicate that if it is necessary to send hyperspectral transfer data from all frequencies in close to-real time, data transfer of more than 1Gb/s will be needed, which exceeds current capacities of military communication systems available for UAS. One of the possible ways of dealing with the limitation seems to be transferring data with the use of coded laser beams. The scale of the problem can be illustrated by the experiences with data transfer with the use of satellite communication from

Global Hawk UAVs during *Enduring Freedom* and Iraqi *Freedom* operations. The procedure required data transfer of 20-40 Mb/s to Beale AFB and data transfer of 6-8 Mb/s to the Air Operations Centre in Kuwait (Office of the Secretary of Defense 2014). As expected, increasing the number of UAVs used simultaneously in the same operational area will result in multiplying the amount of necessary data transfer. Therefore, in the process of determining needs for UAS in the field of communication, one should definitely consider the necessity to provide communication between UAVs and manned aircraft as well as communication between UAVs executing particular tasks in joint air operations.

In the long term plans regarding the development of the Armed Forces capacity to execute combat tasks in accordance with the rules of network-centric warfare, data exchange among particular elements of one's own forces including UAVs will have to be almost continuous. Hence, it is highly probable that in a several years or so, UAVs involved in network-centric warfare will be able to send their location coordinates to air control centres, their own aircraft and other UAVs executing air reconnaissance and combat tasks. Consequently, it will be necessary to standardise data exchange protocols, the frequencies used, as well as communication and computer systems. The process is being introduced both in the USA and NATO countries.

The US Armed Forces are currently implementing standardised procedures for the use of baseline Tactical Common Data Link (TCDL) in air-to-air communication and over-horizon links. TCDL communication should ensure classified, resistant to disturbances data transfer to UAVs (uplink) at 45 Mb/s and from UAVs to recipients (downlink) at 1096 Mb/s. It is expected that the implementation of the Joint Tactical Radio System – JTRS will allow the American UAS to take advantage of self-organising, ''intelligent" communication networks from 225 to 400 Mhz, at data transfer speeds above 5 Mb/s (Joint Tactical Radio System Program Office 2003). As mentioned before, it is possible to compliment UAS radio communication with laser communication. In view of the source literature, we can assume that a particular data transfer with the use of laser data links may be a few dozen up to a few thousand times larger compared to radio communication.

Due to limitations connected with laser beam propagation in the atmosphere in adverse weather conditions such as rain or cloudiness, laser communication is to be used in air-to air relations between UAVs operating at very high altitudes of approximately 20 000 metres.

According to available sources, there are plans to equip Global Hawks with laser communication systems. Nevertheless, it is often pointed out that not all the technical problems connected with data transfer with the use of coded laser beam have already been solved. This applies mainly to *Pointing, Acquisition and Tracking technologies – PAT*.

To sum up, it can be assumed that the UAS requirements in the field of communication will gradually and systematically increase. Taking into consideration the necessity of successful information exchange between UAVs involved in network-centric warfare, as well as transferred data format changes (from text to moving images), the required data transfer speed may be a few dozen times higher than the contemporary one. Such a situation will result in the implementation of new, other than radio, communication systems, mainly laser communication.

Full integration of UAVs used for military purposes in a multinational aspect will require more standardsation procedures to be implemented in numerous countries. Even though technical solution standards regarding the airframe and propulsion systems will be important for logistics, the most significant aspect of UAS standardisation in the next twenty years will definitely be the implementation of unified solutions in the field of information exchange. The thesis is supported by the experiences of the USA and NATO, who adopted common standards for using UAVs in joint operations. The aforementioned standards are presented in the *STANAG 4586 Standard Interfaces for Unmanned Aerial Vehicles Control System* document that codifies the command and control system, data exchange protocols and data formats to be used in contemporary and future UAS in joint air operations[4].

4 The number of standardisation documents regarding UAVs interoperability is increasing: STANAG 4671 - *UAS Air Worthiness Requirements;* STANAG 4670 - *Recommended Guidance for the Training of Designated Unmanned Aerial Vehicle Operator (DUO);* STANAG 7074 - *Digital Geographic Information Exchange Standard (Version 2.1);* STANAG 7085 - *Interoperable Data Links for Imaging Systems*; STANAG 7024 - *Imagery Air Reconnaissance (Digital Tape Storage);* STANAG 7023 - *Air Reconnaissance Imagery Data Architecture;* STANAG 5500 - *NATO Message Test Formatting System Adat P-3;* STANAG 4609 - *NATO Digital Motion Imagery Format (Emerging Standard); STANAG 4607 - NATO GMTI Data Format (Emerging Standard);* STANAG 4559 - *NATO Standard Image Library Interface;* STANAG 4545 - *NATO Secondary Imagery Format;* STANAG 4575 - *NATO Advanced Data Storage Interface;* STANAG 3809 - *Digital Terrain Elevation Data Geographic Information Exchange Standard.*

It is worth mentioning that in view of current UAS development, we should take into consideration the growing number of standardised technical products manufactured by private companies for the civilian sector. Numerous products, including computer processors, operational systems and data formats, are purchased on the civilian market and widely used in UAV on-board control systems. Due to the fact that such products are less expensive than specialised systems dedicated for the military, it is very possible that in the next twenty years or so under the COTS (*Commercial Off the Shelf*) (Edder 2006) programme, commercial technologies for UAS currently available on a civilian market will become much more popular.

Conclusions

On the basis of the current analysis and plans regarding the use of UAVs for military purposes, we can assume that for the next 25 years, the scope of application of UAS will significantly increase. It may be expected that apart from carrying out air reconnaissance tasks, UAS will be capable of executing combat tasks against various types of objects. UCAVs will soon be able to destroy the enemy's air defence assets and strike well protected objects that would be too dangerous for manned aircraft to attack.

Furthermore, it is anticipated that UAVs will be more commonly used in order to execute electronic warfare tasks and provide effective command and control by increasing the communication range. It is also possible that UAVs will gradually take over some surveillance and communication tasks that have been carried out by satellite systems so far.

The research on development trends in the field of Unmanned Aircraft Systems indicates that the predicted changes are much similar to the predictions regarding manned aircraft. At present, the dichotomy of construction largely dependable on the UAVs targeted operational area is one of the characteristic features of their technical development. UAVs designed to execute tasks in relatively safe airspace are manufactured in accordance with the requirements concerning the maximisation of load capacity and flight time at medium and high altitudes. One of the most important requirements regarding UAVs designed to operate in the deep battle area is minimising the possibility of UAV detection and maximising their endurance.

On the basis of numerous studies, we can also anticipate further technical development as far the materials used in UAV manufacturing processes are concerned. It is expected that, apart from carbon composites, isometric materials and even transgenic polymers will be used.

In view of the research, it may be assumed that the propulsion systems currently used in UAVs will be systematically enhanced. In addition, traditional UAV engines may be complimented by fuel cells and solar panels in order to maximise flight time and generate extra energy for on-board electronic systems.

Nevertheless, UAS development process will definitely require numerous interdisciplinary problems to be solved. At present, the most important aspects to deal with seem to be ensuring proper control of weapon use as far as more autonomous UAVs are concerned, integration of UAS with other aircraft in controlled airspace and providing long-lasting interoperability.

The current analysis of UAS development trends indicates, however, that this type of aircraft will definitely not replace, but rather compliment manned aircraft in the nearest future. Therefore, it may be expected that in the next 25 years or so, reconnaissance UAVs will constitute the majority of Unmanned Aircraft Systems used by the military, whereas UCAVs will probably be used to a limited extent due to numerous factors such as the need to conduct further research on this type of UAV. We may also assume that implementing new generations of long-range aircraft able to execute long-haul flights will become an alternative to the development of UCAVs. Thus, the most probable scenario seems to be equipping the military with a relatively small number of UCAVs in order to support tasks carried out by manned aircraft.

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