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Warfare Use of Unmanned Aerial Vehicles

Janusz KARPOWICZ

Military University of Aviation, Dęblin, Poland;
j.karpowicz@law.mil.pl, ORCID 0000-0002-5002-9384

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Abstract

This article contains a summary of the research conducted in the Military University of Aviation concerning the problems of warfare use of unmanned aerial vehicles. It indicates the operational needs of the air force at the modern and future battlefield and the resulting requirements for unmanned aerial vehicles. The present paper outlines the areas of the potential applications and types of unmanned platforms useful for these tasks. It presents the technical and operational requirements and indicates the directions of future research necessary to expand the combat capabilities of these machines. It defines the potential groups of combat and support tasks that may be performed by unmanned aerial vehicles in the future. Conceptual solutions for the use of unmanned platforms at the battlefield and the problems of introducing new means of destruction and extending the autonomy and viability of the platforms are also presented in the present article.

Keywords

battlefield of the future, combat tasks, defense, surveillance and reconnaissance, unmanned aerial vehicles

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1. Introduction

The air force has entered an era in which unmanned aerial vehicles (UAVs) have become not only acceptable but even essential. An example of this reality the case of long-duration observation and reconnaissance operations.[1] When addressing the issue of the use of UAVs in combat operations, the assumption was made to define the needs of the air force, define the technical requirements, develop the principles and concepts of operational tactics during the war and the integration of UAVs in the civil and military environment, i.e. in the common airspace. The first stage of research concerned the theoretical basis of the use of UAVs in combat operations. The research covered five areas:

1) platforms (airframe, propulsion and flight control systems);
2) on-board mission equipment and systems (sensors, data processing and communication);
3) on-board weapons (kinetic and non-lethal weapons and attack systems);
4) mission control systems – human factor (ground/air control, human-machine interfaces and training);
5) operational problems (BM/C4I – Battle Management/Command, Control, Communication, Computers And Intelligence, integration of forces, roles and missions, and new concepts).

In the second stage, on the basis of the accepted theoretical considerations regarding strike aviation support, an attempt was made to define the concept of using UAVs for the suppression of enemy air defenses (SEAD).

The research covered selected battlefield support tasks:

- patrolling and observing areas, gathering intelligence;
- reconnaissance (radar, optical, electro-optical);
- recognition and indication of attack targets (laser beam illumination of targets);
- electronic warfare (including interfering emissions, suppression of the elements of the army command);
- support for search and rescue operations (SAR, CSAR);
- confusing the reconnaissance system and the air defense system, covering the manned aviation missions (UAV as decoys).[2]

The research tasks included the potential combat tasks and those already being carried out with the use of armed UAVs:

- air supremacy combat tasks with the use of air-to-air weapons;

[1] In the research, the term "unmanned aerial vehicle" (UAV) was used. It is a vehicle designed specifically to operate without an operator on board or an aircraft intended to be manned, converted to perform unmanned operations, capable of performing tasks of observation, reconnaissance and attacking or other support tasks in the air (for example, disturbing or jamming the transmissions of the opponent).

[2] Supporting the implementation of tasks in the theater of combat operations includes:

- Intelligence Preparation of the Battlefield (IPB),
- Situation Development,
- Battle Management (BM),
- Battle Damage Assessment (BDA) and
- Rear Area Security (RAS).

Based on: (Wezeman 2007)

– combat tasks related to hitting surface targets with and without the use of kinetic weapons.

The first three tasks are part of the aviation activities defined in NATO as intelligence, observation, targeting, ISTAR (Intelligence, Surveillance, Target Acquisition and Reconnaissance). The research was based on methods of problem and comparative analysis: technical descriptions of equipment and weapons, as well as documents and reports from combat operations. In relation to combat operations and future concepts of warfare, the method of case study and prognosis was used.

2. UAV classification adopted in the research program

From the point of view of the air force, information security and other types of support for aviation operations must cover the area of tactical operations, i.e. 30-50 km from the military demarcation line. Within this space, the tasks of direct support of fighting troops (CAS - Close Air Support) are carried out, and the depth of the enemy territory, where aviation conducts isolation of the combat operations area (AI- Air Interdiction) up to the depth of 500-800 km. For these reasons, there is interest in using UAVs whose technical characteristics allow them to be operated in such a defined space. In the first case, it concerns UAVs classified as tactical of short and medium-range, and in the second, MALE and HALE UAVs forming groups of operational and strategic UAVs. The criteria for classification and characteristics of the exemplary structures adopted in the tests are presented below.

1. Tactical UAVs – short range/low altitude (50-150 km/max. 4,500 m), payload up to 100 kg. Flight duration over 1 hour.
2. Tactical UAVs – medium range/medium altitude (200 km/6,000 m), payload up to 150 kg. Flight duration up to six hours (this group includes the tactical UAV PGZ-19R Orlik).
3. Operational UAV MALE (Medium Altitude, Long Endurance) type – long range, medium altitude (200 km/10,000 m), payload up to 300 kg, flight duration more than six hours, (the research included the MQ-9 Reaper and RQ-170 Sentinel UAVs) (Abraszek, 2009, pp. 60-64).
4. Strategic UAV of the HALE (High Altitude, Long endurance) type – long range and high altitude (range over 1,000 km/altitude over 10,000 m), payload over 300 kg (Wezeman, 2007, p. 16). Flight duration over six hours (Predator C Avanger and RQ-4 Global Hawk UAVs were selected for the tests) (Joint Doctrine Publication 0-30.2. 2017).

The research, conducted mainly by the method of case studies of military operations in two decades of the 21st century, focused on the use of UAVs for the following tasks:

– detection of weapons of mass destruction, mobile tactical and operational ballistic missile launchers, other important mobile military targets and directing manned aviation to these targets;
– observation and recognition of aircraft detection and air traffic control system (radar stations, radiolocation posts) and the military communication and command system;
– destroying ground targets with the use of guided kinetic weapons;
– destroying air targets as part of the air supremacy fight;
– tactical confusion and disruption of communications, command, airspace control and navigation systems.

Within the research, descriptions and other available documents of the above-mentioned air operations were analyzed in terms of operational capabilities and the possibility of using supporting technologies (UAV). As part of the preliminary research, it was found that the leading programs with the use of unmanned platforms, in which the air force may be interested, include:

- electronic interference and aviation activities support within the integrated SEAD operations;
- detection, precise location and neutralization of radio signal transmitters emitted by the enemy at frequencies disrupting own systems;
- image detection and location as well as destroying stationary and moving targets with the use of armed reconnaissance and strike UAVs;
- suppression of enemy air defense for securing the manned aviation operations;
- communication and navigation support of aviation activities;
- deconfliction of airspace management.

The possible range of UAV applications was considered taking into account the following factors:

- the possible scenarios of wars and conflicts;
- types of operations and combat tasks of aviation and their tactical alternatives;
- the relative risk and costs of introducing new UAVs;
- UAV technology maturity and development perspectives.

Initial research allowed for the specification of the main UAV attributes in a comparative analysis with manned aircraft. They were divided into four groups. The first, related to the ability to survive in a hostile environment and significant resistance to countermeasures, results in such operational and tactical advantages as:

- ongoing supervision and information support;
- constant deterrence;
- reduction of the required number of manned units in the theater of operations;
- operating as communication relays in the command system;
- standalone and cooperative operation, including cooperation with manned platforms;
- mission cost decreased.

The lack of crew on board the UAV allows obtaining such features of the UAV and operational benefits as:

- the continuity of operations with a smaller number of platforms, elimination of the fatigue factor of the platform crew;
- the ability to operate in high risk environments (e.g. contaminated environments, air defense zones);
- the ability and profitability of using UAV in a provocative role (decoy),
- potentially simpler construction and reduced cost of purchase and operation;
- reduced need for crew training and combat protection;
- lower reliability factor and less accurate safety test required;
- potential use for a suicide mission;
- less extensive support and protection of the mission than in the case of manned aircraft.

The benefits resulting from automation and autonomy of the unmanned platform include the following:

- less complex, less costly training for operators than that of the manned aircraft pilots;
- no safety systems and tests for the crew, no protection and rescue systems required;
- simpler design of the programming and control interface for unmanned aircraft;
- reduced physical requirements for operators.

The UAV's ability to operate at high altitudes and depths favors the exposure of such operational features as:

- the ability to far-detect objects in the air and on the ground;
- wide viewing angle of Doppler and SAR radars;
- large range of data transmission from the UAV board and retranslation of external signals or emissions;
- favorable geometry for Tactical Ballistic Missiles (TBM) destruction missions (Worch, et al, 1996, pp. 3-4).

Figure 1. Remote Piloted Air System (RPAS) MQ-1 Predator, used by the American military. Predator's payload consists of for or eight Hellfire Missiles AGM-114C or AGM-176B Griffin (INS / GPS + semi-active laser guidance) with a weight of approximately 15 kg with a range of 8 to 20 km; and two Paveway II laser guided bombs GBU-39B, GBU-58 or GBU-44/B Viper Strike. Adopted from: "Amerykańskie Reapery w bazie w Mirosławcu". Radar rp.pl, by Z. Lewitowicz, Copyright 2019 by the Publisher. *https://radar.rp.pl/wojsko-polskie/13633-amerykanskie-reapery-w-bazie-w-miroslawcu*

3. Missions and operational tasks concepts

The research covered a review of the current air support tasks performed for the benefit of other types of troops, and it was determined which of them can be performed instead of or supported by unmanned aerial vehicles. The possible contribution of the currently available UAVs to the typical strike aviation tasks on the battlefield was also considered.

Three basic types of strike aviation activities were selected for the research – strategic air activities against leadership, the armed forces and the economy, and activities against land forces, including direct air support and strikes against troops and objects in the tactical zone, as well as a group of air isolation tasks and within its framework, attacks on troops and objects outside the tactical zone. The activity of strike aviation against the enemy air force was also considered. This activity includes the fight against the enemy air force on the ground by striking airplanes and air bases, as well as fighting enemy air defense system facilities by performing strikes against defense measures as well as missile and radar systems (Karpowicz, 2008, p. 248).

A number of factors were taken into account in the assessment of UAVs capabilities. They included the characteristics of the platform, the degree of vehicle/flight autonomy, management, reliability, airspace planning procedures, survival procedures, deployment (dislocation) requirements, combat capabilities (impact with kinetic and non-destructive weapons), information support, communication systems (information), survivability, command and control (C2), autonomy and the human factor.

The research covered three main types of aviation combat operations: actions against enemy land forces, actions against air force and air missions in the form of a strategic attack.

When it comes to the combat aviation needs, the following aspects were adopted as critical aviation tasks within the framework of the above-mentioned types of activities: combating weapons of mass destruction; searching and destroying ballistic missiles and self-guided missiles; destroying important permanent and mobile military targets in the tactical and operational zone; suppressing enemy air defense; intelligence, surveillance and target acquisition (ISR); electronic warfare; securing communication; positioning and indicating targets for air strikes and missile forces.

The listed key tasks of aviation find practical and technological solutions in tactics, and UAVs bring significant potential to strengthen the capabilities of the Air Force by supplementing the existing structure of forces and combat capabilities (Zieliński, 2010).

Combating weapons of mass destruction is high on the list of tasks for unmanned aviation. The ability to locate and destroy weapons of mass destruction (WMD) can determine the success of a campaign. The operational concepts include the use of UAVs for observation, recognition and tracking, as well as in the positioning of mobile means of delivery of these weapons. Basically, the task of destroying the detected targets belongs to the manned aviation, but equipping UAVs with precision weapons allows it to take over these tasks.

Modern sensors and UAVs reconnaissance capabilities predispose a group of operational unmanned reconnaissance aircraft to the tasks of determining the possession, production, storage and movement of nuclear materials, materials and devices for the production of biological and chemical weapons (NBC) by opponents. UAVs can effectively complement other forces in carrying out this difficult and complex task by taking advantage of their long-term presence in close proximity to the sought targets.

It is also possible to destroy such materials by UAVs with dual equipment (multispectral sensors and kinetic weapons) or reconnaissance UAVs in conjunction with weapon carriers. Making a decision to use precision penetrating weapons or specialized kinetic charges will require an assessment of the side effects of such an attack in terms of environmental impact (combat damage assessment).

The tasks of searching for and destroying mobile ballistic missile launchers and cruise missiles (Theater Missile Defense - TMD and Theater Ballistic Missile - TBM) is the second significant task of aviation in the struggle for supremacy on the battlefield. Considering the durability and resistance of UAVs in counteracting enemy air defense measures in the tactical zone and beyond it, such platforms are even predestined to take over this important mission from the manned aviation, especially when it is not possible to temporarily or

permanently suppress the enemy's air defense. The effectiveness of the UAVs support for the manned aviation results from their ability to stay over the enemy's territory for a long period of time, penetrate both the tactical zone and the back of the fighting troops, while being resistant to the enemy's air defense system. Additionally, high-altitude armed UAVs with the characteristics of impaired detectability may supplement the shortage of manned systems counteracting ballistic and self-guided missiles.

The implementation of this task has so far been based on an independent (without external support) visual search for important targets, e.g. ballistic missile launchers by the crews of airplanes and/or helicopters in designated zones. This method is called Combat Air Patrol (CAP). Due to the high degree of risk, this method was used after gaining air supremacy. It was a particularly risky task, as the crews were exposed to attacks from the enemy's unneutralized air defense measures. The use of UAVs is not subject to the mentioned tactical limitations. This task can also be performed together with the manned aviation during other types of air operations, e.g. as part of the isolation of the battlefield.

The tasks of tracking, recognizing and fighting command centers with the use of UAVs may include both electronic disruption of the operation of military command and control systems, as well as destructive influence of armed UAVs on the sensitive elements of these systems. Experience in the field of counter-terrorism allows to assume that reconnaissance and strike UAVs can be used to identify and even physically eliminate important people from the opponent's leadership.

Generally, such tasks are to be carried out as part of an air-based strategic attack, in which aviation, acting alone, will strive to reduce the enemy's defense capabilities and their will to fight, as well as during combined air-ground (sea) operations.

As part of air operations against land forces, UAVs can be involved in supporting the manned aviation during the implementation of air isolation tasks and direct support for troops.

Combat UAVs can be used to attack fixed surface targets of high value during aviation operations as part of strategic air attack (SA), close air support (CAS) and isolation of the combat area (Air Interdiction - AI). Direct aviation support mainly covers the fight against operational reserves, but may also be used to neutralize material resources (ammunition and fuel depots) and structural resources (command and control network, communication network).

The place and tasks for UAVs will be taken into account during the planning and implementation of all forms of tactical aviation strike groups, i.e. *Force Flow* and *Force Package*, both during mass and selective strikes.[3] As part of selective strikes with the use of precision means of destruction, UAVs will be particularly able to provide information and fire support to the manned aviation.

As part of these types of operations, armed UAVs can, apart from suppressing the enemy's air defense, perform the following tasks: recognizing and marking important targets in a group of fighting troops, such as command posts, artillery, missile and armored units, and air force of the land forces. An important task for these UAVs will be to detect and mark objects in the back of the fighting troops, such as: army groups, armaments warehouses, reserves, airports and airstrips as well as air bases. The manned aviation using this information and the support of the UAVs will be able to carry out the task of supporting the troops operation effectively.

[3] The *Force Package* option enables the use of single, fully autonomous tactical groups, formed by strike and support aircraft, intended to combat individual objects or groups thereof in a limited area. The *Force Flow* option uses a large number of strike groups to combat a wide range of impact targets.

As part of support for strike aviation activities, UAVs will perform image reconnaissance (composition, arrangement, sensitive elements of the target), GPS positioning and other targeting data, e.g. about targets, masking, weather in the area of the strike targets, by providing information about the targets of the planned strikes,.[4] The data from the UAV, delivered in advance and updated during the mission, will eliminate the need for direct reconnaissance and will make it possible to reduce the size of the COMAO combat group. The condition is that the strike aircraft are adapted to receive various forms of information directly from the board of these planes. Unmanned aerial vehicles will also be used to control the results of the impacts. If there are no such possibilities, the reconnaissance is carried out by aircraft from the tactical group (Karpowicz, 2008, pp. 250-251).

Fighting against fixed and mobile targets by manned aviation in the tactical and operational zone with precise means of destruction, from medium and high altitudes, outside the fire zone of short-range artillery and missile air defense systems, may be supported by unmanned aerial vehicles. Attack from high altitude with guided means of destruction requires special targeting equipment and good weather conditions because the planes remain at a considerable distance from the targets, and it is difficult to detect them and identify the prescribed hit points. For these reasons, the indication of targets or the directing the guided means of destruction to targets is more and more often performed by reconnaissance unmanned aerial vehicles equipped with appropriate equipment (e.g. laser target/hit point pointer) and groups of special forces, including relevant specialists.

High-altitude and high-endurance operational and tactical UAVs in this type of operations can provide long-time observation as well as image and electronic reconnaissance of the part of the enemy territory of key importance for the manned aviation mission. Connected in a C2 network architecture, HALE reconnaissance UAVs can provide information about impact objects to the air command stations or directly on board of manned platforms during their flight to the destination. If it is not possible to suppress the enemy's air defense, the missions of searching for and destroying fixed and mobile targets on the battlefield or in the back room may be taken over by armed UAVs (Brzezina & Chojnacki, 2008).

Intelligence, Surveillance, Reconnaissance – ISR. Acquiring information about the enemy and the potential air strike targets is carried out in the air force by conducting observations and air reconnaissance. The collection of data obtained by the air force is used to determine the intentions of the potential opponents, to detect and select targets for impact, and to possibly determine the effects of actions taken by own forces (Intelligence, Survey, Target Acquisition and Reconnaissance – ISTAR Operations).

Aerial observation consists of continuous or systematic observation of a selected segment of the airspace, land or sea surface to detect changes taking place there. It is not assumed in advance what objects are to be observed. However, the location and period of time the observation should be carried out and what constitutes the object of the observation in general are determined. In the case of aerial reconnaissance, the action is aimed at detecting, locating (defining the position by measurement or other means) and determining the state or activity of a predetermined reconnaissance object.

The technical and tactical properties of the UAV perfectly meet the needs of a relatively safe stay over the enemy territory, approaching targets being objects of interest to the troops and long-term observation, and tracking and recognition of their activity. This al-

[4] Targeting is the process of selecting targets, prioritizing them, and selecting and implementing an appropriate method of impacting these targets, taking into account operational (tactical) requirements and possessed possibilities. See: *USAF Intelligence Targeting Guide*. Air Force Pamphlet 1998, access 21.04.2021 [in:] https://fas.org/irp/doddir/usaf/afpam14-210/index.html

lows for precise determination of the location of the detected objects and any changes in this range. These UAV capabilities are generally defined as: "the ability to provide the necessary and up-to-date intelligence data from anywhere in enemy territory, day or night, regardless of the weather, for military purposes".

Electronic warfare (IW/EW) is defined as military operations involving the use of electromagnetic energy, including Direct Energy (DE), to use and dominate the electromagnetic spectrum or to attack an enemy (AJP-3.3, 2016) This type of warfare includes the interception and identification of electromagnetic emissions, the use of electromagnetic energy to limit or prevent the use of the electromagnetic spectrum by the enemy, and actions ensuring the effective use of the electromagnetic spectrum by own troops (forces).

UAVs can operate at high altitudes for a long time (even 24 hours) without refueling, and thanks to their low detectability, they can avoid threats from enemy air defense systems. Due to their considerable payload, they can carry electronic support measures (ESM) and electronic counter measures (ECM) on board.

The considerable flight endurance allows for electronically covering both single impact missions and large COMAO formations over a large area. In another support concept, jet UAVs equipped with electronic warfare systems could lead a COMAO formation providing jamming of radar stations tracking and guiding systems of enemy air defense missiles and other recognized electronic means.

Jamming UAVs can also play the role of decoys in a formation, which, replicating the signature of a manned aircraft, would engage the enemy's guidance and anti-air defense systems.

Suppression or destruction of enemy air defenses (SEAD / DEAD) is any activity that neutralizes or temporarily disrupts surface anti-aircraft defense by overwhelming or destructive use of air defense measures (Joint Pub 3-01.4, 1995).

For manned aviation, overcoming air defense countermeasures during the flight over the line separating troops and combat operations zone is a complex tactical task. The flight itself has an increased degree of risk (Worch, 1996). In addition to manned aircraft with reduced detectability (stealth), UAVs can be engaged in the tasks of suppressing the enemy's anti-aircraft defense as part of comprehensive electronic fire destruction of the elements of the air defense system. In the fight against air defense, the elements of the radar reconnaissance, command and destruction subsystem may be the object of the UAV's influence. The main form of influencing these measures is fire and electronic strike. Support in this matter can be provided by UAVs equipped with electronic warfare systems and combat means of destruction. It is assumed that while performing tasks over the enemy's territory, UAVs should remain outside the firing zone of small arms and anti-aircraft artillery (Worch, 1996).

The UAVs used for SEAD tasks should be able to fly safely over areas defended by integrated ground-based air defense systems. The stealth features of the BSP platform are required in this respect. In addition, the UAV must be able to provide the operator in the control center with a real-time image of the tactical situation, collected by the observation radar and optical recognition system (TV, Video), which is necessary to make an attack decision. The UAV armament must be capable of self-guiding to the source of electromagnetic emission of the missile guidance station or at the indicated hit point of the recognized target. It should have a range of min. 5 NM, as it is assumed that this distance allows for the recognition of most small-sized mobile targets with weak unmasking characteristics (Joint Pub 3-01.4, 1995).

UAVs can detect the enemy's electronic air defense system's emission means and transmit the emission characteristics and precise location data to the SEAD aviation command posts. This will allow stealth strike aircraft equipped with SEAD/DEAD weapons to

plan and safely execute their attacks (Worch, 1997). Many circumstances indicate that in the near future, these tasks will be fully taken over by unmanned platforms (North, 1997).

Securing retranslation in command and reconnaissance networks

An unmanned platform can be used to carry out multi-range unmanned communication relays securing the connection and data transmission between the ground command posts of the troops fighting and moving over a large area.

The value of such support is manifested in most offensive phases of operations when the tactical communication network is limited in keeping up with fast moving forces, not only in physical speed but in power, frequency, throughput, available channels and avoiding enemy interference. Separated and widely dispersed land forces are often out of sight and thus also out of the reach of VHF communication. Thanks to UAV retranslation, they would receive effective support.

Communicating reconnaissance information over appropriate networks, including fighting troops, also often requires amplifying or re-translating emissions.

Air supremacy combat in the form of Offensive Counter Air/Deffensive Counter Air combat is defined as an air activity directed against offensive and defensive means of the enemy air force in order to obtain and maintain the desired degree of air supremacy. The combat can be offensive or defensive.

Offensive actions include: countering enemy aviation at airports and in the air; destroying elements of the enemy's air defense system; destroying elements of the aviation command system and anti-aircraft defense; and fighting down elements of the enemy's air force support subsystem (infrastructure and resources). Offensive actions rest with strike aviation, which is assigned the task of destroying the enemy's air force on the ground and bases located on its territory. Defensive actions are the responsibility of air defense ground system and fighter aviation.

BSP can be engaged in defensive and offensive air supremacy combat. It is envisaged that unmanned aerial vehicles armed with air-to-air missile weapons will be used to fight the enemy aviation at forward borders, even over enemy territory. Armed UAVs that remain beyond the capabilities of radar detection can create advanced ambushes and surprise attacks on single planes and combat formations with air-to-air weapons. It is also planned to use fighter UAVs for offensive air combat, basing the success in combat on maneuverability significantly exceeding the parameters of manned aircraft, extended autonomy and self-guiding short-range weapons.

Unmanned aerial vehicles will also fulfill the functions of manned aviation support in these activities by direct recognition of attack targets and indicating targets for precision ammunition strikes, incapacitating or destroying air defense means of the impact targets and re-translating communication in aviation command networks.

4. Factors for assessing the capabilities of the UAV combat applications available to the air force

Several of the characteristics of UAVs deserve special attention: operational height, combat readiness and continuity of operations, technical reliability and durability, operational compatibility.

The above-mentioned tactical and technical properties of UAVs, which are desired for future applications, generate new technological challenges for UAV platforms. Research has shown that the following areas can be included:

a) enhancing the stealth properties of the airframe and on-board (outboard) weapons;
b) image recognition and data collection and processing;
c) the technology of adaptive-autonomous control systems;
d) the development of propulsion system technology in order to reduce fuel consumption and increase flight endurance, reduce unmasking thermal and acoustic emissions (noise reduction) and electromagnetic emissions;
e) new types of weapons dedicated to UAV – low weight and dimensions, self-guiding (fire and forget) and guided (laser beam, TV, IR), modular control and shock heads (kinetic, electromagnetic).

The general direction of technological changes of on-board systems is to maintain the current level of efficiency, while radically reducing the size, mass (weight), energy consumption affecting flight endurance and costs (construction, maintenance, operation, purchase).

5. New weapon systems dedicated to the UAVs

With regard to operational needs, phased development works on new missiles with modular warheads were initiated, allowing for the future fulfillment of the spectrum of UAV and manned aircraft combat missions. The key is a number of innovative, modular warhead technologies ensuring the achievement of extensive capabilities in the field of targeting and kinetic impact in small-size and low-mass UAV-compatible weapons.

The family of weapons developed for the UAV is adapted to the new potential combat tasks envisaged in the operational concepts.

1. Rocket weapons required to intercept a ballistic missile during the launch (climb) phase (Boost Phase Intercept – BPI). A hyper-fast projectile with a kinetic charge and an infrared warhead.
2. Penetrating missile with a modular warhead (kinetic for destroying permanent targets and SEAD tasks; penetrating (flechette) for striking reinforced targets; microwave HPM capable of disrupting and destroying electronics and radio devices).
3. Low-cost, small-size subsonic cruise missile, guided by GPS/INS, with modular warheads, for various UAV missions, as part of the Low Cost Autonomous Attack System (LO-CAAS) capable of autonomous search, classification and destruction of the target.
4. Low-mass tactical missiles armed with High Power Microwaves (HPM) warheads.

Air-to-air missile. The current concepts of UAV combat applications provide for their use in actions against the enemy air force, as part of offensive and defensive air supremacy combat. Air-to-air UAV functions are currently limited by the level of autonomy and the payload size and weight of the available air-to-air missiles, as well as the detection range of UAV sensors (radar). Therefore, the Sidewinder (AIM-9) and AMRAAM (AIM-120) missile families are expected to be suitable weapons for short and medium range applications.

Figure 2. MQ-9 armed with the AIM-9X Block 2 missile. Adopted from: "MQ-9 Reaper new weapons test", US Air Force, by A.H. Stevens, Copyright 2021 by the Publisher https://www.konflikty.pl/wp-content/uploads/2021/02/200903-F-UA265-1057.jpg

Implemented precision-guided munitions programs (PGMs) Air-Launched: Paveway Laser Guided Bomb, Joint Direct Attack Munition (JDAM), Small Diameter Bomb, Small Diameter Bomb II, Hellfire Missile, Joint Air-to-Ground Missile, Joint Air-to-Surface Strike Missile (JASSM), Long Range Anti-Ship Missile (LRASM), and Advanced Anti-Radiation Guided Missile (Precision-Guided Munitions .., 2021).

Small-sized ammunition adapted to unmanned platforms:

a) guided missiles: AGM-176 Griffin (Raytheon) JAGM (Joint Air to Ground Missile) (Lockheed Martin) – platforms: MQ-1 Predator, MQ-8B Fire Scout, MQ-9 Reaper;

b) small-size guided bombs: Hatchet (ATK); ADM (Air-Dropped Guided Mortar) (General Dynamics); SABER (Small Air Bomb Extended Range) (MBDA); (GBU-44/B) Viper Strike (MBDA); platforms: MQ-5B Hunter, RQ-7 Shadow, MQ-1 Predator, MQ-9 Reaper (Glajzer, 2016).

6. Limitations of extending the autonomy of UAVs

Airborne Lethal Autonomous Weapon (ALAW), or Autonomous Air Weapons System (AAWS), is a type of unmanned air-to-air combat system that can independently search for targets and attack them based on programmed characteristics and constraints.

Currently, the autonomy of such systems is limited in the sense that a human gives the final command to attack – although there are exceptions for some "defense" systems.

It is controversial to delegate more military tasks and potentially some key decisions to computers and algorithms installed in weapons capable of violent action against humans. The most ethically contested capabilities of the new autonomous systems lie deep in the software code. The autonomy of the system means that it can make some decisions by itself. Theoretically, advanced software could allow the new UAV to decide on its own whether to attack an enemy plane, destroy the enemy's missile launchers or radar, or bomb a convoy of vehicles or a factory. Due to legal and ethical issues, it is likely that no autono-

mous system will ever be left to make such decisions. Any future autonomous air systems will be under the control and command of highly qualified ground or air operators, who will also be able not only to remotely pilot the unmanned aerial vehicle, but also to decide about its combat functions.

7. Final conclusions

In the very near future, unmanned aerial vehicles will not only be able to collect data on the target's location but also – due to the increasing autonomy granted to them – use weapons to destroy them.

Fighting tasks with the use of air-to-air weapons are being intensively developed among the UAV combat applications. In the superiority and supremacy combat, UAVs can be engaged in defensive operations, providing information support (detection of air targets) to the anti-aircraft defense system and fighter aviation, and for offensive operations independently in the form of an air ambush or in joint formations with fighter aviation (increasing range of detection and destruction of fighter aviation).

Concepts of using UAVs as a swarm of subordinate wingmen, guided from a manned platform, occupying positions on extended borders, in order to detect and attack an air enemy early, well beyond the detection range of ground-based radars, are being tested. The idea is to allow a single pilot-operator to run several semi-autonomous, artificial intelligence, and unmanned aerial vehicles from their own cockpit. In this way, the role of a human would change from a fighter pilot-operator to a system mission commander.

The concepts of using UAVs for strike tasks with the use of precision ammunition, in operations over the enemy territory, in high-risk areas, in the form of air patrols, operating autonomously in designated areas (kill boxes), independently searching for and fighting against the ordered, saved in the memory of the on-board computer and detected targets.

It is necessary to envisage extending the combat tasks of the UAV after completing work on the new types of weapons and ammunition dedicated to the UAV.

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