Analysis on the Operation Mode of UAV Swarm in Urban Combat

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Abstract. With the acceleration of the urban process, the city will gradually become the main battlefield of the future warfare. While urban warfare will become an important combat style of future warfare, while UAV swarms will play an important role in urban combat with their unique combat performance. This paper explores the capability advantages, application methods and challenges of UAV swarms in urban combat, and considers the ways of generating combat capabilities, hoping to serve as a theoretical and practical reference for exploring UAV swarm urban combat.

Keywords: Urban combat · UAV swarm · Application method

Cities are the political, military, economic and population centers of a country. Occupying or controlling cities with military and strategic values can boost the morale of military, disintegrate the fighting will of opponents, generate huge psychological advantages, and help accelerate the process of war and achieve war objectives quickly. However, due to the sensitivity of urban warfare and the complexity of battlefield, the battle space is compressed, the battle time is prolonged and the battle fiercer and crueler, and it is difficult to achieve the ideal combat effect. The use of "small but sophisticated", "small but strong", "small but complete" and "small but wise" UAV swarms can effectively overcome the disadvantages in the previous urban operations, greatly improve the combat effectiveness of combat and achieve operational effects.

1 UAV Swarm Capability Advantages in Urban Operations

Compared with other combat styles, urban combat has very different operational characteristics, such as complex battlefield environment, high combat cost and high casualty rate. The application of UAV swarm combat can greatly improve combat effectiveness and has huge operational advantages, which are mainly reflected in the following aspects:

First, UAV swarm has a flexible mobile combat capability. Urban buildings are tall with dense, iterative layers, forming building complexes. The streets are stretched out in all directions but blocked by buildings on both sides of the street, the maneuverable space is limited. The complicated underground passage system makes it difficult to break through promptly. Traditional conventional weapons are difficult to give full play to their power advantages, and are prone to collateral damage from accidental strikes and

explosions. The portable UAV swarm with smaller body can take off and land vertically in any region and form an operational capability within a few minutes. It can carry out operational tasks by flying flexibly above the streets in tall buildings and narrow streets.

Second, UAV swarm has a strong battlefield survivability. All the individuals contained in the drone swarm are independently dispersed, not centralized and do not have dominant control, the crashes or failures of any individual, or individuals will not affect the overall function, individual airframe has a strong survivability due to its advantages of low cost, quick production and easy assembly, because it can be complemented quickly after being destroyed.

Third UAV swarm has the great efficiency and fee exchange advantage. Small UAVs can be produced by 3D printing technology, with outstanding unit price advantage. In the process of actual combat, due to the large number of individuals in the drone swarm and their scattered distribution, and the ability to maintain a high-pressure posture of continuous combat, the enemy often requires several times or even one hundred times cost to combat and protect, which will significantly boost the enemy's operational costs and, also indirectly bring themselves cost-effectiveness exchange advantage [1].

2 Application Mode of UAV Swarm Urban Warfare

With its outstanding cost-effectiveness ratio, good flexibility and mobility, and strong battlefield survivability, UAV swarm can fight independently or cooperatively, and can carry out "soft killing" as well as "hard destruction". With the innovation and breakthrough of "Swarm" single platform and key technology, UAV swarm will become the key force to complete "human cannot" task in order to win the future urban warfare, at the cost of "human treasure", and in the "human cannot" environment.

2.1 All-Round Reconnaissance and Surveillance

In modern warfare, the right of information is particularly important. The right to Obtaining information means gaining the first opportunity to win. Traditional conventional intelligence surveillance and reconnaissance means are satellite reconnaissance, radar detection, traditional UAV reconnaissance and special operations forces latent reconnaissance. Radar detection will form blind areas or weaken detection range due to the occlusion of urban buildings. Satellite reconnaissance and surveillance will also produce blind areas due to the barriers of building walls. Traditional unmanned aerial vehicle is easy to be detected due to its large radar cross-section area and loud noise. Special operations forces have low efficiency of latent reconnaissance and are easy to be killed. These traditional conventional means will be destroyed and intercepted by ground air defense weapons when implementing reconnaissance and surveillance. The UAV swarm adopts vertical launch mode, which is not restricted by geographical area, and has small radar reflective cross-sectional area, weak infrared characteristics, and low flight noise, which can effectively reduce the probability of being by radar, photoelectric and acoustic detection system. It has the inherent characteristics of low interception and low detection probability. Even in the case of losing air control, it can also conduct real-time,

large-scale, high-precision, and non-blind spot monitoring and detection of urban battlefield through low-altitude and ultra-low-altitude flight, accelerate OODA cycle and effectively improve the commander's ability to perceive and control battlefield situation. During the Russia-Ukraine war, the Ukrainian army was equipped with a large number of Dajiang quadrotor UAV, which have carried out reconnaissance and surveillance tasks on the Russian army for many times without being detected, have captured a large number of pictures of Russian troops moving on the road, and guided the artillery and anti-tank missiles strikes, causing most casualties among Russian troops.

2.2 Diversified Adaptation Strikes

UAV swarm can adopt modular, serialized and replaceable load design, plug-and-play temporary replacement, carry out full-dimensional, compound attack against the enemy, finally accomplish a variety of combat missions effectively.

First, saturation attack. Under the condition of tall building block and detection blind area, UAV swarms with low probability of detection are used to avoid detection by radar, photoelectricity, infrared and other means. They fly intensively from different directions and at different heights, so that the detection, tracking and interception capabilities of the enemy's urban air defense system quickly reach saturation and become paralyzed. Then they cover the fire channels of the enemy defense system with absolute numerical superiority, and then use their own high-performance attack to ultimately, achieve operational effect. In the NK conflict in 2020, Azerbaijan used TB-2 drones to form a drone swarm to conduct a large-scale attack on Armenian ground combat equipment such as artillery, tanks, armored vehicles in the form of saturation attack, achieving good operational results.

Second, precision strikes. In the urban environment, where military personnel are mixed with ordinary civilians and military equipment is interwoven with the deployment of livelihood facilities, and traditional conventional weapons are prone to causing collateral damage when carrying out strikes, which is difficult to achieve the desired effect. UAV swarm can be loaded with reconnaissance and detection, target recognition, fire attack and other task loads, or the missile patrol UAV can be used to break through the urban air defense system, and carry out the integrated operation of precise detection, accurate identifications, precise attack on important targets, achieving combat effects under the premise of effectively controlling the killing range. The "Killer Bee" micro-UAV, which was publicly demonstrated by the United States in November 2017, can carry 3g of high-powered explosives to kill targets accurately through face recognition, and can be used for targeted elimination and precision attack in urban buildings or among crowds, achieving effects that cannot be produced by conventional weapons [2].

Third, distributed kill. In urban warfare, the key weapon system will rely on the scattered and concealed configuration of urban buildings. Due to the limitation of attack angle, the target cannot be accurately covered in conventional means, resulting in poor attack effectiveness. The UAV swarm can be mixed and grouped with various combat functions of the UAV platform in accordance with the mission requirements, constituting a comprehensive combat group that integrates reconnaissance and perception, deception and interference, firepower confrontation and other capabilities, to conducts "soft" and "hard" compound attacks on the target area in multi-dimensional airspace and from

multiple directions, and at the same time to achieve the destruction of point targets and surface area strikes.

2.3 Relay Coordinated Operation

Although UAV swarm has the absolute advantage in urban warfare, due to the limitations of specific operational requirements, limited load capacity and tactics technology performance, the UAV swarm cannot completely replace the manned equipment to perform combat tasks, but can work with manned equipment in concert, The combination of both manned and unmanned combat, can enhance the operational efficiency.

First, Coordinated operation with people. Modern urban buildings adopt concrete walls of broad thickness and one-way perspective glass, which have the characteristics of shielding electromagnetic radiation, shielding visible light source, and isolating imaging reconnaissance. UAV swarm can carry out close harassment, forcing the enemy to expose the hiding position, while interfering with the enemy attack, UAV swarm transmit the captured target information, and then use precision-guided munitions to implement accurate fire destruction.

Second, Jamming decoy deception. According to the interference principle, under the condition of constant interference power, if the interference distance is reduced by 1/10, the interference intensity can be increased by 100 times [3]. Taking advantage of the small radar reflection cross-sectional areas which is not easily detected, the UAV swarm carries jamming load and flies close to the target area, acts as baits, or carries out electromagnetic feints, and then obtains a strong jamming suppression effect with the same jamming power, and finally obtains the electronic parameters of the enemy's equipment. During the NK conflict, Azerbaijan used the An-2 drone as a bait to lure the Armenian air defense radar to turn on and expose the radiation sources, and deliberately allowed it to be shot down to expose the location of the air defense missile. After captured the radar radiation signals by Harop drone, An-2 drone carried out the precise attacks on the 5P85S transmitter and the ST-68U/UM radar of the S-300 air defense system. Then the TB-2 drone conducted the supplemental strikes against the S-300 air defense battalion, which eventually destroyed it completely.

Third, Terminal guidance. The efficient reconnaissance capability of UAV swarms can enable close detection and positioning of obscured areas, detection blind zones and hidden targets simultaneously, and quickly transmit the related data to the fire strike unit, or directly conducts target indication, ballistic correction and parametric calibration for attacking munitions to improve the strike accuracy of the target and to enhance the interception probability of the enemy's attacking weapon [4]. On March 10 of this year, The Defense Ministry of Ukraine released a video saying that the Ukrainian artillery units conducted a precise attack on Russian armored column through a drone calibration at a distance of 15 km from the urban area of Kyiv, which blocked the speed of the Russian army.

3 Effectiveness Analysis of UAV Buzzer Suppressing Air Defense Weapon

In order to explain the damage probability of UAV bee colony to air defense system more clearly, the simulation method is used for analysis and research. In actual combat, the urban air defense weapon system is deployed by a mixture of multiple types of air defense weapons, so as to achieve the optimal air defense operational efficiency. For the convenience of calculation, only the damage probability of a certain air defense weapon caused by the drone swarm composed of 15 UAVs is analyzed in the simulation process.

Hypothesis: Assume that the main task of a certain type of air defense weapon is to use its own firepower to destroy the UAV trying to enter the target radius of 2 km; A small UAV with a takeoff weight of 10 kg is used. Each UAV can fly autonomously in a 90°sector without synchronizing with other UAVs in the hive; The detection range of air defense weapon's own radar to depends on the UAV's flight altitude, which is about 1–3 km. If the simulated attack time of UAV bee colony is 10 min, the average damage probability of air defense weapon to a single air target is $p_0 \approx 0.25$. The priority of target (p) is determined according to the minimum available time (t) of air defense weapons:

$$p = min\left\{t_i | t_i = \frac{R_i cos\varphi_i}{V_i cos\theta_i cos\psi_i} + \frac{\delta_i}{\omega_o}\right\}$$

R_i – inclination distance to the i_{th} UAV;
ϕ – Pitch angle to the i_{th} UAV;
V_i – flight speed of the i_{th} UAV;
θ_i – Inclination of the i_{th} UAV motion track;
ψ_i – relative heading of the i_{th} UAV;
δ_i – Deviation angle between the direction axis of air defense weapon and the azimuth of the i_{th} UAV;
ω_0 – Rotation angle speed of air defense weapon direction axis;
i – UAV number;
p – Priority of influence on UAV.

Simulation results of air defense weapons against UAV swarm attacks as shown in Fig. 1:

It is illustrated through the simulation calculation that air defense weapons cannot ensure effective protection of targets. 11 of the 15 UAVs have entered the responsibility area of air defense weapons and succeeded to attack and damage targets (Fig. 2). It proves that the survival probability of the air defense system is poor under the large-scale raids of drone swarms, and theoretically proves that the drone swarms can successfully destroy or break through the air defense system. The case of Husai's armed attack on Saudi oil fields with 18 drones and 7 cruise missiles also proves this.

The results show that the use of drone swarms to suppress air defense systems has become an important way in modern air defense operations. Since the density of air defense missile systems against targets is limited to a small number of channels where air defense weapons aim at targets at the same time, and drones may also carry electronic jamming equipment to interfere with air defense weapon channels, which can further reduce the probability of being destroyed, simply increasing the number of air defense
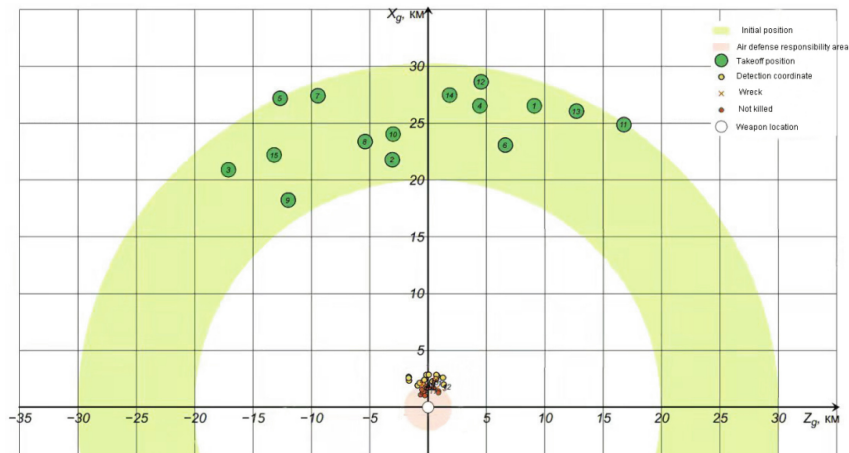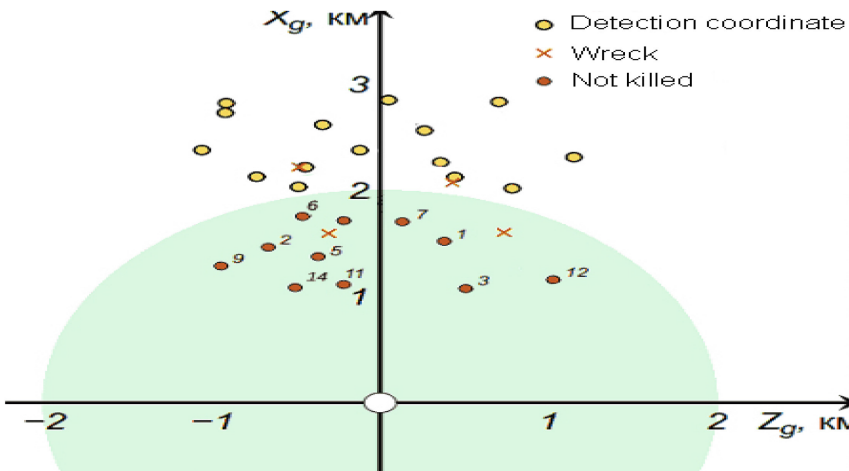
Fig. 1. Simulation effect

Fig. 2. Kill result

weapons is not the most effective way to defend drone swarms. The large-scale use of bee colony warfare can also make the air defense fire channel reach saturation quickly, and further lead to paralysis, thus increasing the penetration probability of UAV bee colony.

4 Thoughts on the Development of UAV Swarm Urban Warfare

DARPA released the initial concept of OFFSET in December 2016 [5], in which combat research and ideation design should be based on typical urban combat scenarios, and the research and experiments need to be gradually carried out. China conducted a coordinated

flight of 119 fixed-wing UAV swarm in June 2017, successfully demonstrating actions such as intensive catapult takeoff, airborne assembly, multi-target grouping, formation closing, and cluster action [6], which have not yet been specifically applied to urban warfare research. UAV swarm warfare is a new mode of modern urban warfare, which is in the initial stage of exploration and has a huge space for innovation and development. If we can play the leading role in the USA swarm combat research on generation of combat effectiveness and combat application, it is easy for us to seize the opportunity and win the initiative in future urban warfare. Therefore, we need to make efforts from the following aspects:

First, we need to make overall planning, design of research and development. It is necessary to coordinate the military and local quality resources to complement each other, joint military and local related forces to pool their wisdom and research, set up a special plan for UAV swarm urban combat, break through the key technologies such as anti-collision and obstacle avoidance, navigation and positioning and communication interference, to accelerate the formation of a highly distinctive asymmetric technology route, and finally achieving the purpose of having what you do not have, being better than what you have had and becoming the best of all, to accelerate the formation of a highly distinctive asymmetric technology route.

Second, we need to promote military doctrine innovation. The cognitive exploration of new things is always difficult and uncertain. It is necessary for us to build an up-to-date, leading and unique combat theory research system suitable for modern war, boldly explore unoccupied areas in the field of urban combat for the UAV swarm applications, highlight the UAV swarm urban combat theory research, proactively design warfare based on future urban combat theory, and constantly seek breakthroughs in the innovation of combat concepts, the exploration of winning mechanisms, and the revelation of the laws of war.

Third, we should focus on talent development. Mao Zedong once pointed out that "weapons are an important factor in war, but not a decisive factor. The decisive factor is people, not things" [7]. The typical characteristic of UAV swarm is "no one on the platform but in the system". Human participation is needs and requirements are higher no matter which session the person appears in. It is necessary to accurately grasp the standards and requirements of unmanned combat talents, immediately introduce guiding policies and measures, and strengthen personnel training through military-civilian integration to provide talent support for promoting unmanned combat.

Fourth, we should conduct solid troop training. It is necessary to strengthen the training of unmanned combat thinking, implement the training of unmanned combat skills, deepen the training of unmanned combat command, highlight the cooperative training of unmanned combat, incorporate the research on UAV swarm combat into daily combat readiness exercises, carry out training research by using VR technology and simulation technology, and organize specialized, intensive and critical combat training relying on the urban combat training ground, so as to enhance the actual combat capability of real combat readiness, fine attack and good defense, and control and smart control.

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