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RESEARCH ON THE LAUNCH AND RECOVERY METHODS OF UAV

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Abstract: With the continuous progress of science and technology, the UAV launch and recovery method has also undergone an iterative update. Stable and reliable launch and recovery technology determines whether the UAV can play its due operational effectiveness in a modern war. Around the study of UAV launch and recovery, the research status of domestic and abroad is introduced, analyses the corresponding technical principles and gives typical cases. Meanwhile, the advantages and disadvantages of different methods are compared and analysed to provide choices for the methods of UAV launch and recovery. This paper discusses the lack of universality of launch and recovery methods, low cluster launch capability and low technology integration in practical application, and gives suggestions and prospects for technological development, hoping to achieve the further purpose of promoting UAV launch and recovery technology.
Keywords: UAV; Launch technology; Recycling technology; Cluster operations; Weaponry

1 INTRODUCTION

Unmanned Aerial Vehicle, or UAV, is a kind of aircraft that can fly independently, be driven by its own power and can be used repeatedly [1]. Because it breaks through the physical limitations of human and aircraft pilots, it has gained a broad space for development in the military field, and is widely used in rescue, intelligence gathering, communication interference and reconnaissance and early warning. Compared with the traditional manned aircraft, the UAV has the advantages of small size, simple operation, low production and maintenance cost, and low requirements for combat environment [2-4].
With the update and development of UAV technology, the supporting launch and recovery technology is also constantly innovating. Whether the UAV can be launched safely is directly related to the survival ability, the reuse ability, the combat area adaptability and the flexible response ability of the whole UAV system in the battlefield. The complex and changeable battlefield environment will affect the launch of the UAV, so the safe launch capability is regarded as one of the important indicators to evaluate the UAV [5]. On the other hand, the landing and recovery stage of the UAV occupies a small workload, but in the process of performing the mission, once the failure occurs, it will cause great damage to the UAV. According to statistics, the faults caused by recovery accounted for more than 50% of the total drone failure. Therefore, UAV recovery technology has become one of the key technologies related to the development of UAV. Whether the recovery task can be completed safely is an important indicator to evaluate the performance of UAV [6-7].
The problems existing in the current launch and recovery technology greatly restrict the efficiency of release UAV in combat operations. In order to solve the problems existing in the current UAV launch and recovery device and improve the combat effectiveness of UAV, proposing new launch and recovery technology solutions becomes a key step.

2 UAV LAUNCH TECHNOLOGY

Nowadays, the domestic and foreign UAV launch methods are generally divided into the following types: hand throw launch, roll off launch, rocket-booster launch, catapult launch, air launch and vertical take-off launch.

2.1 Hand Throw Launch

The hand throw launch method is very simple, just by the operator in a certain direction, like a paper throwing plane to throw the drone to take off. Due to the use of human mode, it is only suitable for small micro or lightweight drones, such as the "Big crow" in the United States, China's "Rainbow" -902, etc.

2.2 Roll off Launch

The take-off mode means that the UAV with landing gear takes off along the runway under the thrust of its own engine [8]. Such as the "Global Eagle" of the United States, Australia's "Jindivik" and so on. The advantages of this take-off mode are the simple and reliable structure, mature technology and low ground support pressure; the landing gear increases the weight and volume of the UAV and requires a runway in good condition with poor mobility.

2.3 Rocket-Booster Launch

A rocket booster launch is the way that uses the chemical energy generated by the booster to convert it into kinetic energy [9]. Such as "RQ-2" in Israel and "ASN-206" in China. The method generally adopts zero-long emission or short-range guide rail emission [10]. Therefore, it has the advantages of low cost, strong mobility and good environmental adaptability, but the disadvantages of noise, strong light and smoke restrict the large-scale promotion of this method.

2.4 Catapult Launch

Ejection take-off launch is the method of converting different forms of energy into kinetic energy to accelerate the UAV to take-off in a certain length of orbit. The source of emission kinetic energy can be divided into elastic potential energy, gas / hydraulic energy and electromagnetic energy. The elastic potential energy emission [11]. With the use of the elastic potential energy of the elastic element to "bounce" into the air, its simple structure and low cost, only suitable for launching micro, light drones, such as the British "cone"; air / hydraulic ejection. It refers to the use of pneumatic / hydraulic pressure catapult to launch the UAV, with a relatively mature and flexible launch technology, such as the British "undead bird"; electromagnetic ejection [12-13]. It refers to the electromagnetic energy generated by electromagnetic field, which has high launch efficiency and is suitable for different types of UAV, but the equipment has high technical requirements and expensive cost, such as China's "HK-5000G".

2.5 Air Launch

Air launch refers to the use of aircraft, missiles and other carriers to carry drones into the air in the way and separate the launch. For example, the "MQ-9" Reaper UAV of the United States launched the "Sparrow Eagle" UAV in the air, and the Israeli F-4 hanger carried the "Dille" unmanned, bait aircraft. The simple operation of air delivery reduces the probability of the UAV being intercepted, but the flight carrier should be equipped with ground support facilities, with high maintenance cost and poor mobility.

2.6 Vertical Take-off Launch

The vertical take-off launch is different from the above launch method, and the launch direction is perpendicular to the runway and can hover in the air. The power sources of this launch mode can be divided into two categories, one is to take off vertically, the other is to rely on the lift generated by its own rotor, such as "Dragonfly" and "Dragon Warrior" in the United States. This launch method requires no runway and can meet the needs of hover tasks [14], But it only applies to specific types of drones and is not popularized.

Through a comprehensive analysis of the basic principles of the above UAV launch methods, most of them need to power the take-off speed and altitude through different ways at a certain launch site, to make its successful launch. The following Table 1 summarizes the advantages, disadvantages, and typical models of existing launch methods.

Table 1 Summary of launch methods

Method	Advantage	Disadvantage	Typical models
Hand throw launch	Extremely simple	Only suitable for micro drones, difficult to control during operation	"Big crow" in the United States, China's "Rainbow" -902
Roll off launch	Simple structure, no need for ground support	High runway requirements and large takeoff weight	"Global Eagle" of the United States, Australia's "Jindivik"
Rocket-booster launch	Low cost, strong mobility, and good environmental adaptability	Fuel is difficult to store and transport, and the emission process produces sound, light, and smoke	"RQ-2" in Israel and "ASN-206" in China
Catapult launch	Mature technology, low cost, and good universality	Emission quality is limited	the British "undead bird", China's "HK-5000G"
Air launch	Easy to operate, reducing the probability of drone interception	The carrier needs to be equipped with ground support facilities, resulting in high maintenance costs	the United States launched the "Sparrow Eagle" UAV in the air, and the Israeli F-4 hanger carried the "Dille" unmanned bait aircraft
Vertical take-off launch	No runway required, low launch environment requirements	Only applicable to specific types of drones	"Dragonfly" and "Dragon Warrior" in the United States

3 UAV RECOVERY TECHNOLOGY

With the increase of dispatch missions, the UAV is required to be recycled to improve the utilization of a single UAV. Minimal failures in the recovery process can cause damage to the entire drone, so the ability to stabilize the landing and recovery becomes critical. The existing recovery technology mainly includes parachute recovery, recovery of buffer air cushion, interception net recovery, intercept rope recovery, roller run recovery, vertical landing recovery and air recovery [15].

3.1 Parachute Recovery

Parachute recovery refers to the recovery method in which the UAV opens its own parachute after receiving the command and uses the generated air resistance to slow down and land [16-17]. The technology is relatively mature and simple structure, easy to operate, so it is used in light UAV on a large scale. Such as the "fire bee" of the United States, China's "long arrow" and so on. Although the whole recovery is completed by the UAV, without the assistance of ground personnel, its own parachute increases the load of the fuselage, and the landing stage is easy to be affected by the environmental wind, which has a certain risk of failure. According to the landing site, the parachute recovery can be divided into land recovery, water recovery and high-altitude recovery.

3.2 Recovery of Buffer Air Cushion

Buffer air cushion recovery refers to the recovery method of using the airbag carried by the belly position of the UAV machine to form the air cushion when near the ground or water [18], to avoid the violent impact with the contact surface. The recovery method is simple and easy to install, not limited by terrain conditions and the size and weight of the UAV, with strong environmental adaptability, high mobility and low cost; but the structure and material selection of the air cushion will also affect the uncertainty of the recovery success.

3.3 Intercept Net Recovery

Interceptor recovery refers to the use of elastic materials to intercept the UAV in flight and slow it down to zero in a very short period of time, such as the "silver fox" and "killer eagle" in the United States. The interceptor network recovery system usually consists of the interception network, the energy absorption buffer device and the end guide device [19]. This method can be regarded as zero long recovery, which is suitable for fixed recovery in a limited area. The recovery process is stable; but the interception network area is narrow, and the UAV enters the interception network, so the implementation of the method is complicated, with high requirements on operators and is susceptible to environmental factors.

3.4 Intercept Rope Recovery

The interception rope recovery can be divided into horizontal recovery and vertical recovery according to the direction of the rope placement [20], the former needs to install an interception hook in the belly or tail of the UAV, and adjust the flight altitude to buffer the interceptor rope; the latter needs to install the interception hook on the wing tip of the UAV, and recycle it after taxiing operation, such as the "scanning Eagle" in the United States. The two modes are simple in structure, easy to arrange, suitable for narrow areas, and the vertical recovery mode requires low requirements and higher fault tolerance; but they have high buffer performance requirements and high requirements for the control level of the UAV.

3.5 Roller Run Recovery

Roller run recovery is similar to manned landing, which refers to the recovery method of running landing by using the friction between the landing gear and the ground. At the same time, the tail hook can be installed at the tail, and the blocking rope and blocking net can be used to shorten the running distance. Such as Israel's "pioneer", the American's "X-47B" and so on. The runway of this method has low requirements, the UAV bears small overload, and the working process is reliable, but the recovery distance is still long, and the mobility is poor.

3.6 Vertical Landing Recovery

Vertical landing recovery is only suitable for rotor drones or special fixed-wing drones, which use the rotor as a power source, such as China's Red Dragon 850; the latter uses engine thrust to counteract gravity, such as Israel's Hermes-450. This method is not limited by terrain, mobile and flexible, but it is very difficult to develop the thrust vector technology with special fixed wing, and the input cost is high.

3.7 Air Recovery

Air recovery refers to the way for the UAV to slow down and open the hook umbrella and sling while lowering the height after receiving the command, waiting for the manned to approach for recovery [21]. For example, the United

States successfully recovered the "elf" drone in the air on October 29, 2021. The only advantage of this approach is that it does not damage the drone; but the recovery process requires manned pilot proficiency and vulnerability to weather and wind, causing high cost and low success rate.

To sum up, there are many recovery methods for UAV, and the most appropriate methods should be further selected according to the specific requirements to increase the success rate of recovery. The advantages and disadvantages of recycling methods and representative models are summarized in the Table 2 below.

Table 2 Summary of recovery methods

Method	Advantage	Disadvantage	Typical models
Parachute recovery	The technology is relatively mature and the structure is simple, making it easy to operate	Increase the load on the aircraft body, making it susceptible to environmental wind during the landing phase	"fire bee" of the United States, China's "long arrow"
Recovery of buffer air cushion	Not limited by terrain conditions and the size and weight of drones, with strong environmental adaptability	Uncontrollable inflation process of air cushion	Australia's "Jindivik"
Intercept net recovery	Zero length recycling, suitable for fixed-point recycling in limited areas, with a smooth recycling process	Difficulty in interception and susceptibility to environmental factors	"silver fox" and "killer eagle" in the United States
Intercept rope recovery	Simple structure, easy to arrange, suitable for narrow areas	High requirements for aircraft control capability	"scanning Eagle" in the United States
Roller run recovery	Drones can withstand minimal overload and operate reliably	The recycling distance is still relatively long, and the mobility is poor	Israel's "pioneer", the American's "X-47B"
Vertical landing recovery	Unrestricted by terrain, flexible and maneuverable	Applicable only to specific drones, difficult to develop thrust vector technology	China's Red Dragon 850, Israel's Hermes-450
Air recovery	Will not damage the drone	High cost, requires skilled driver skills, and is susceptible to environmental impact	"elf" in the United States

4 PROSPECT OF UAV LAUNCH AND RECOVERY TECHNOLOGY

With the continuous progress and development of UAV technology, its functions and uses have been continuously expanded, especially the emergence of the concept of cluster operations in the military field makes it a reality to replace the UAV as the main fire point, and the successful launch and recovery has become an important index to evaluate its performance. In recent years, military powers have attached great importance to the research and development of air-launched drones and related testing work. Since 2013, the U.S. Navy has gradually carried out technical research and experimental verification work on launching the Unmanned Targeting Air System (UTAS) based on the P-8A anti-submarine patrol aircraft platform. The Perdix drone cluster project, led by the U.S. Department of Defense, completed demonstration tests of aerial cluster flight and reconstruction in 2016. The Defense Advanced Research Projects Agency (DARPA) of the United States is advancing the concept of distributed air combat and launching the Gremlins air-to-air UAV project. In October 2021, it completed demonstration and verification tasks based on transport aircraft for air launch and recovery, and has preliminary combat application capabilities. Under the guidance of the "Air Launch Effect" project, AERA-I Corporation of the United States has developed the "Agile Launch, Tactically Integrated, Unmanned System" (ALTIUS), an integrated unmanned system. In recent years, it has successively carried out test launch and flight missions on platforms such as helicopters and loyal wingmen. However, in China, this aspect is still in its early stages, and there is relatively little research and literature on it.

Summarize the existing launch and recovery technology, although some methods have been widely used, there are still the following technical problems at this stage [22], need for further research and development.

(1) Lack of universal applicability. Since the emergence of drones, the research on the corresponding launch and recovery methods has been put on the agenda. So far, there are various kinds of UAV launch and recovery methods, each of which has its own applicable model. According to the corresponding launch and recovery methods according on the types of drones, the final results can only be applied to the model, while the complex UAV models lead to the complex launch and recovery methods. Up to now, there is still no launch and recovery method that is generally applicable to various models and meets the requirements of different environments, far from reaching the unity and universal applicability of technology.

(2) The cluster emission level is low. With the wide application of small drones in the military field, how to launch large cluster drones in a short time has become a research hotspot. Most of the existing launch and recovery methods are carried out for a single UAV, and there is more support equipment, long layout time and poor mobility, which greatly reduces the combat efficiency of the UAV. Due to the lack of large-scale launch and high frequency rapid recovery, the progress of UAV group integration is greatly restricted.

(3) The technology integration degree is not high. UAV launch recovery technology is often divided into two areas, the existing launch recovery technology mostly needs two sets of independent device use, greatly increased the drone launch load, and even occupies part of the task load space, reduces the efficiency of the drones, is not only a waste of space, more improve the development cost.

As the UAV tends to high altitude timing, stealth, air combat and swarm, based on the limitations of the existing launch recovery technology, the direction of future technology development is as follows.

(1) In view of the complex and changeable battlefield combat environment in the future, higher requirements are put forward for the adaptability of the launch and recovery environment. Therefore, the development of zero-long launch and precise fixed-point recovery technology has become the key.

(2) According to the requirements of UAV cluster technology, the capacity of large-scale mass launch and high-frequency rapid recovery is taken as the design index requirements, and devices that can continuously launch and achieve rapid recovery are vigorously developed.

(3) In view of the low integration degree of launch and recovery technology, we are required to highly integrate the two technologies, strengthen the integrated design, reduce the waste of UAV space and cost, and promote the development and progress of UAV.

COMPETING INTERESTS

The authors have no relevant financial or non-financial interests to disclose.

REFERENCES

[1] Tao Y J, Li P F. Overview of UAV system development and key technologies. Aeronautical Manufacturing Technology, 2014, 20: 34-39.

[2] Xiao N Z. Analysis of military application of UAV swarm technology. 2020 3rd International Conference on Unmanned Systems (ICUS), 2020, IEEE: 1200-1204.

[3] Kapustina L, Izakova N, Makovkina E, et al. The global drone market: main development trends. SHS Web of Conferences. EDP Sciences, 2021, 129: 11004.

[4] Jackman A. Consumer drone evolutions: Trends, spaces, temporalities, threats. Defense Security Analysis, 2019, 35(4): 362-383.

[5] Zou X F, He Q H, He J L. UAV development status and related technologies. Flying missile, 2006.

[6] Cui M H, Zhou J J, Chen C. Discussion on key technologies for UAV shipborne applications. Aeronautical Science and Technology, 2004, 5: 31-33.

[7] Kuang S G, Liu D C. An Overview of the development of shipborne UAVs. Flying missile, 2003, 2: 16-19.

[8] Siddiqui B A, Rahman H U, Kumar C, et al. Computer aided modeling and simulation of pneumatic UAV catapult mechanism. 7th International Mechanical Engineering Congress, 2017, 24-25.

[9] Li H, Xiao Q G, Hu S S. Modeling and simulation of the take-off and launch section of the rocket-propelled UAV. Journal of Southeast University, 2010, 40 (9): 136-139.

[10] Bao C M, Liu C L, Sun Y. UAV launch technology and its development. Flying missile, 2012.

[11] Yang C S, Yin X S, Jiang H N, et al. Research on UAV launching system based on rubber tendon rope ejection. Modern Manufacturing Technology and Equipment, 2017, 11: 67-68.

[12] Bolyukh V F, Kocherga A I, Shchukin I S. Electrodynamic Catapult for Unmanned Aerial Vehicle. 2020 IEEE KhPI Week on Advanced Technology, 2020, IEEE: 159-164.

[13] Mikhail V S. Drone Launched Short Range Rockets. Aerospace, 2020, 7(6).

[14] Wang G L, Wu Z. Vertical take-off and landing technology and its application in UAV. Flying navigation missile, 2006, 06: 20-25.

[15] Cao L, Geng B B, Zhou L, et al. Research on the development of UAV cluster launch and recovery technology. Space and Space Defense, 2019, 2 (02): 68-72.

[16] Wu H, Wang Z, Zhou Z, et al. Research on dynamics behaviours of small UAV parachute recovery system. International Journal of Mechatronics and Automation, 2020, 7(3): 156-164.
[17] Wu H, Wang Z, Zhou Z, et al. Modeling of small UAV parachute recovery system based on lagrangian method. 2019 IEEE International Conference on Mechatronics and Automation. 2019, IEEE: 1127-1132.
[18] Li X B. Air cushion landing system scheme design and landing simulation analysis. 2017, Nanjing: Nanjing University of Aeronautics and Astronautics.
[19] Pei J H. UAV collision network recovery technology. Journal of Nanjing University of Aeronautics and Astronautics, 2009, 12: 6-8.
[20] Skitmore A. Launch and Recovery System for Improved Fixed-Wing UAV Deployment in Complex Environments. Unmanned Aerial Remote Sensing, 2020, 303-316.
[21] Jorgensen D S, Haggard R A, Brown G J. The Past, Present, and Future of Mid-Air Retrieval. AIAA 2005-1673.
[22] Liu Y B, Xue K, Wang C K. Research on UAV development trend abroad. Engineering and Testing, 2020, 60 (03): 41-42,64.