Analysis of the "Loyal Wingman" Technology of UAV Cooperative Operation

Jing Lei[1][1], Jia-Qing Song[2], Yan-Yan Zhu[1]

School of Mathematics and Statistics, Taishan University, Tai'an 271000, China[1]
Experimental Teaching Management Center, Taishan University, Tai'an 271000, China[2]

Abstract: The use of UAVs in the battlefield will promote the development of unmanned cooperative operations and greatly change the mode and form of future operations. In view of the application and research of "wingman" technology in UAV cooperative operations, this paper explores the concept of "loyal wingman" and the research overview of various countries, so as to provide a reference for the in-depth development of UAV cooperative intelligent operations.
Keywords: drones, coordinated operations, loyal wingmen

I. Background

Unmanned Aerial Vehicle (UAV) is an unmanned aerial vehicle on board, which uses aerodynamic flight, can be controlled remotely or autonomously, carries a mission load, can be reused, and is also an aerial robot. A complete unmanned aerial system (UAS), in addition to the UAV platform and the mission payload it carries, also includes ground command and control systems, data communication equipment, launch/recovery devices, maintenance equipment, etc. Due to the wide application and excellent performance of UAVs in modern warfare, their research has gradually attracted the attention of various countries, and all military powers in the world are actively developing and manufacturing their own UAVs.

With the continuous development of UAV technology and performance, the demand for its military mission is also increasing, in this case, a single UAV can no longer meet the mission requirements, and the formation of multiple UAVs can not only improve the completion rate of the task, but also greatly improve the combat effectiveness of the system. Multi-UAV cooperative operation refers to the joint marshalling of the aviation combat platform and the aviation combat operation platform composed of UAVs in the environment of informatization, networking and system confrontation to implement cooperative detection, coordinated electronic countermeasures and coordinated attacks.

The multi-UAV collaborative technology is of great significance in both theoretical and engineering applications, and has also achieved many excellent research results. With the continuous breakthrough of new UAV technology, the "cooperative operation" of UAV formation will make full use of the advantages of cooperation and coordination, strengthen the overall advantage, and greatly improve the overall combat capability of UAV formation, which is bound to become the direction and development trend of the next generation of UAV research.

At present, various research institutions at home and abroad have conducted a lot of research on the development trend, key technologies and combat applications of unmanned cooperation. Based on the above background, this paper analyzes the multi-UAV wingman in cooperative operation.

II. "Loyal wingman" concept

(1) Concept

In 2015, the U.S. Air Force Research Laboratory (AFRL) proposed a concept called the Loyal Wingman and officially launched its research project to target formations of manned aircraft and drones, with the aim of seeking the combat capabilities of such formations. The Loyal Wingman program defines the wingman's combat role as an attack as a launch platform, to remove interference in advance and attract anti-aircraft fire, and to interfere outside the defense zone. Self-combat formations of loyal wingmen are capable of accomplishing the following combat missions: they can have a clear and clear understanding of combat missions; they can independently carry out mission planning; wingmen can confirm communications and analyze and report information to the long plane; they can start to carry out tasks autonomously without clear notice from the long plane; and they can dynamically modify the combat plan to adapt to different combat

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[1] Corresponding author: elizabethia@126.com

scenarios and tasks.

At this stage, the American Loyal Wingman program has made some progress. The U.S. Air Force Research Laboratory has set up a background for the application of drone warfare, and has made public a possible combat mode called loyal wingman. The main body of application of this mode is a combat formation composed of four unmanned loyal wingmen controlled by a manned chief aircraft and controlled by a long aircraft. Among them, the manned long plane is the core of the entire formation, and in addition to commanding all loyal wingmen, it is also necessary to undertake the task of coordinated operations. The command of the chief aircraft to the wingman is done in the form of task assignment. Assignment is not only to set two separate targets for a separate loyal wingman, but also to determine the return time and position of the wingman when returning. On the basis of the confirmation that these indicators can be completed, the long aircraft must also take into account additional factors such as operational risks and the minimization of fuel consumption. Such a complex and comprehensive combat scheme design and control logic enable the unmanned wingman with autonomous capabilities to be competent for the task of penetrating the fifth generation manned aircraft in some high-risk operations. Manned long planes can command unmanned wingmen in addition to the enemy's anti-aircraft fire, so that they can not only efficiently carry out the task of discovering and destroying targets, but also ensure the safety of manned aircraft and protect them from enemy anti-aircraft fire.

(2) Combat scenarios

Based on the characteristics of the QF-16 and the UAV combat framework, the possible combat scenarios of the US "loyal wingman" are as follows:

(a) manned aircraft (F-35) as a long aircraft, commanding four UAV wingmen (QF-16);

(b) the long aircraft assigns independent targets to the loyal wingmen and carries out separate strikes;

(c) UAV wingmen play the role of penetration in front of manned aircraft, performing tasks such as target search, tracking, and strike;

(d) Manned aircraft command and control outside enemy anti-aircraft fire to reduce the threat of manned aircraft.

(3) Key technologies

The key technical fields involved in the "loyal wingman" of UAV include: power technology, adaptive and distributed mission planning technology, sensor fusion technology, combat identification technology, task prioritization and distribution technology, communication adaptability technology, driver-applicable interface and workload management technology, and man-machine mission reporting technology after the mission.

(4) Advantages

From the point of view of combat effectiveness, the combat concept of "loyal wingman" combines manned fifth-generation aircraft and unmanned fourth-generation aircraft into combat formations, and with the help of the fifth-generation aircraft's role as a combat network node, it can give full play to the advantages of the fourth-generation aircraft in good maneuverability and sufficient firepower, thereby enhancing the lethality of these two aircraft in air combat.

III. Analysis of the "loyal wingman" of various countries

(1) The U.S. "Loyal Wingman" program

In 2015, the U.S. Air Force proposed the concept of "loyal wingman" based on "manned aircraft/UAV marshalling technology", combining fifth-generation fighters and unmanned fourth-generation fighters into a formation, with the help of the fifth-generation aircraft's combat network node role, giving full play to the advantages of good maneuverability and sufficient firepower of fourth-generation aircraft, thereby greatly enhancing the lethal killing ability of both in air combat. This combat concept is to hope that in most dangerous environments, a drone can play a breakthrough role in front of a fighter jet and undertake the task of discovering and destroying targets, so as to effectively ensure that the fifth-generation fighter is far away from dangerous situations and avoid being subjected to deadly counterattacks from opponents. In the requirements of the released plan, it is also proposed that UAVs can carry more weapons to complete air and ground strike missions, which echoes the concept of "arsenal aircraft".

A key part of the implementation of the "loyal wingman" mode of operation is the modification of the fourth-generation F-16 fighter. As early as the late 90s of the 20th century, Lockheed Martin began to study the technology of converting the F-16 fighter into a full-size target aircraft in response to the training and testing needs of the US Air Force, adding remote control and communication equipment of no more than 136 kg on the basis of retaining all the functions of the manned fighter, converting the F-16 into a manned/unmanned dual-role fighter, and completing the autonomous take-off test of the QF-16 target aircraft in September 2013. The QF-16 also has a lot of potential as a drone that can fly over the target in a timely manner with a much faster speed.

Thus, the MQ-16, an improved UAV based on the QF-16, can strike under enemy anti-aircraft fire, clearing the way for fighters and attack aircraft that follow closely.

In terms of development goals, in addition to the modified manned fighter in service, the combat "loyal wingman" will also consider using a low-cost and expendable unmanned fighter, such as the "XQ-58" Valkyrie ("Valkyrie"), which has the maneuverability and weapon delivery ability similar to that of a fighter. The concept of "loyal wingman" can also be applied to the combat mission style of other models of manned aircraft and UAVs.

Both the fourth-generation UAV modification (QF-16) and the XQ-58 are "implanted" with artificial intelligence methods, with cooperative flight and automatic collision avoidance capabilities, autonomous planning capabilities based on mission priorities and available resources, new sensors and payloads, and the ability to perform tasks such as detection and attack under the control of manned aircraft, and even autonomously respond to changes in the threat environment in an increasingly complex environment.

On July 20, 2015, an article published on Australia's Daily Aerospace website said that the U.S. Air Force Research Laboratory plans to conduct a demonstration and verification of the UAV "Loyal Wingman" project in the 2020-2022 fiscal year, showing how the UAV wingman can cooperate with manned aircraft in a high-confrontation environment. A request for information has been issued, focusing on key technologies that can support the autonomous capabilities of UAVs.

UAV "loyal wingman" refers to a drone capable of fighting in formation with fifth-generation fighters. They will be able to enter combat areas that are inaccessible to manned aircraft, and will be able to operate in situations where GPS signals and communications are disrupted, without the need for ground operators to control and command from manned aircraft at all times. After the mission is completed, they will autonomously return to the take-off base or other designated airfields.

The first part of the UAV "Loyal Wingman" Concept Demonstration Verification is an attack mission demonstration and verification, which is planned to be conducted in FY2020, focusing on the use of UAVs to deliver weapons or target designation for manned aircraft. The second is the demonstration and verification of the task of suppressing enemy air defense, which is planned to be carried out in fiscal year 2022, and will use drones to discover, confirm and locate enemy radars, which alone or in concert will carry out in-zone or out-of-zone jamming, preemptively launch anti-radiation weapons or launch weapons after coordination with manned aircraft. The RFP notes that during operations, drones may face some degree of GPS signal jamming or spoofing, electronic warfare, a certain number of threat sources, and temporary interruptions or disconnections of satellite communication signals.

Regarding the role of UAV "loyal wingmen" in combat, the Air Force Research Laboratory pointed out that if a group of UAVs are involved in combat, they must cooperate with each other. In combat, they may act as weapons-carrying aircraft, with manned aircraft providing target information, and when manned aircraft attack, they act as decoys to deceive enemy air defence systems. In addition, they can be used as data nodes to integrate the intelligence gathered during the mission.

From the progress of typical unmanned cooperative projects such as the "loyal wingman" and "Valkyrie" of the United States, it can be concluded that the US military will focus on the development of unmanned cooperative operations in the future.

(2) Russian "Altair" - U

According to an article published on the website of the Russian newspaper "Izvestia", the arsenal of the Russian Aerospace Forces will add a new "killer" - a "higher" heavy attack drone, which can autonomously perform tasks without command and return to base. Russian experts believe that the new features will turn the "higher" into an all-round weapon. Judging from the aerodynamic shape and some of the details mentioned in the report, the 'taller' heavy attack drone should be the 'Altair'-U drone. "

On August 20, 2019, the Russian Ministry of Defense released video materials showing that the first flight of the "Altair"-U UAV was successful. This UAV is a medium-altitude long-endurance reconnaissance and combat integrated heavy UAV developed by Russia itself, with a take-off weight of 6 tons. "Altair"-U is the latest modification of the "Altair" family of UAVs.

The "higher" UAV is similar to the American "Reaper" Chada UAV, both in terms of take-off weight and bomb load, both are quite close. It has a straight upper wing and V-tail layout, is equipped with two turboprop engines with a power of about 800 hp, flies at an altitude of 12,000 meters, and has a space time of between 24 and 48 hours. The nose part of the nose is raised, and a satellite communication antenna should be installed to have satellite communication capabilities. The "higher" UAV can not only be remotely controlled by the ground station within the visual range, but more importantly, it can also be remotely controlled thousands of kilometers away through satellite communication. These functions are similar to the "Reaper", in a sense, the "Reaper" drone on the "higher" drone has heavy traces.

Allegedly, the "higher" heavy attack drone will be equipped with an artificial intelligence component to

bypass enemy air defense systems without command, search for the most important targets on its own and strike them, and then return to the base with a full body retreat. At the same time, it can also accept the remote control of the Su-57 fighter and carry out manned and unmanned cooperative operations with the Su-57.

The upgraded 'higher' drone will serve as a wingman for the Su-57 in the future. This requires it to develop new artificial intelligence control software, develop new algorithms, upgrade the computing power of the central computer, so that the 'higher' UAV can better fly with the Su-57 formation, and at the same time, after accepting the Su-57 command, it can independently plan the route of action and the timing of the target.

But it may be difficult for the "higher" UAV to become the wingman of the Su-57. Because their speed and flight altitude are too different. The Su-57 is a high-speed aircraft with a maximum speed of more than Mach 2, while the speed of the "higher" UAV is too slow. It is very difficult to coordinate operations between them, and a lot of research work has to be carried out on coordination. For example, the "higher" UAV can fly to the mission airspace one step earlier, and then wait for the Su-57 to fly before receiving instructions to carry out the mission. But in this way the suddenness of war is lost, and it is inefficient.

The "higher" UAV and the American "Valkyrie" UAV are a whole generation behind. "Valkyrie" belongs to the high subsonic stealth UAV, which was really developed according to the concept of "loyal wingman". The development of the "higher" drone began in 2011, but it only made its first flight in 2019, and the process is quite long. This indicates that Russia may encounter technical difficulties or insufficient financial guarantees. However, after the "higher" UAV is equipped with artificial intelligence components, if the long wingman cooperation is not considered, it is only used as an intelligent UAV, and its combat value is very high. Because it can autonomously perform tasks after takeoff, which is more advanced than the Reaper drone.

The task undertaken by the 'higher' UAV that is benchmarked against the 'Reaper' should be a similar integrated reconnaissance and combat mission, which is more suitable for low-intensity combat missions such as counter-terrorism. Judging from the similar aerodynamic layout and functional positioning of the two, the 'higher' UAV, which does not fly at a high altitude and has a relatively slow speed, should not be suitable for use in high-intensity war conditions, because its penetration ability is not strong. Even if artificial intelligence can be relied on to avoid danger points in the future, it is difficult to use it in high-intensity warfare because it does not have stealth capabilities.

(3) China's "Feihong-97A"

At the Zhuhai Air Show, a group of highly intelligent unmanned aerial vehicles made their public debut, they are like "guards with knives" accompanied by manned fighters, providing intelligence, information and firepower support, this avant-garde weapon system is a "loyal wingman" called "Feihong-97A" developed by the Aerospace Science and Technology Group Ninth Academy Feihong Company.

At present, the industry generally believes that the "loyal wingman" is expected to subvert the traditional manned aircraft air combat mode, create a new ecological niche in the original air combat system, and change the original fighter formation long, medium and short range air combat mode. On the one hand, it can expand the pilot's perception and strike range, on the other hand, through large-scale, clustering, and generalized use, each wingman can become an intelligent node in the air combat system, obtain local combat information, and screen and fuse to form a global battlefield situation, assist pilots in decision-making, and protect people from danger. The highly tense combat environment is liberated, so that the pilot can become a commander of a flight formation in addition to a traditional pilot.

As a drone that can provide forward reconnaissance and fire support for manned combat aircraft, the attack and defense power of the "Feihong-97A" has also attracted much attention. The embedded bomb bay of the "Feihong-97A" can carry eight miniature intelligent air-to-air missiles, and the underwing and belly also have extended payload capacity, which can be used to hang auxiliary fuel tanks, air-to-air missiles, precision-guided weapons, electronic warfare pods and other equipment according to mission requirements. In addition, the defense of this type of drone is also very strong. Thanks to the intelligent skin antenna technology, this "loyal wingman" has good anti-jamming ability, and also has a low detectable shape and intelligent maneuver evasion ability.

IV. Conclusion

As a product of the combination of new concepts and new technologies, the "loyal wingman" will greatly change the way and form of future operations. This paper analyzes the concept of "loyal wingman" and the current research status of various countries. In the future, this technology will accelerate the research of key technologies, promote the integration of artificial intelligence technology and UAV collaboration, and promote research in the field of UAV collaborative operations.

References:
[1].   Lai Yaosheng, Li Long. Analysis of American Loyal Wing and Its Power Development [J]. Aviation Power, 2022, (04): 14-17
[2].   Zhu Chaolei, Yuan Cheng, Yang Jiahui, et al. A review of the development of foreign military drone equipment technology in 2021 [J]. Tactical Missile Technology, 2022, (01): 38-45
[3].   Da Jun. Loyal wingman [J]. Elementary School Science, 2020, (08): 30-33
[4].   Zheng Dazhuang The concept of "loyal wingman" will significantly enhance the collaborative combat capability of manned/unmanned aerial vehicles [J]. Defense Perspectives, 2016, (06): 63