Research on integrated logistical support systems of medium altitude long endurance UAS

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Abstract. The Medium Altitude Long Endurance (MALE) UAS in modern warfare is becoming more and more widespread, which makes the UAS more and more frequently used in warfare. The equipment characteristics of UAS are embodied in the following aspects. The composition of UAS is complex, Ground Stations is distributed deployment, Mission payloads can flexibly change, and the whole system need highly cooperative ability between air and ground. That put forward higher requirements for integrated logistical support system of UAS. Aiming at the unique support characteristics of UAS, this paper constructs the integrated support system of UAS based on the integrated support system of traditional aircraft, which is mainly reflected at five aspects: support organization, support resources, support function, support process and support management. This systems can ensure the integration of all support links in the actual process of UAS support, and meet the operational and mission requirements of UAS to the maximum extent.

1. Introduction
Since the 21st century, the Medium Altitude Long Endurance (MALE) UAS has developed rapidly, its combat scope and application form are more and more extensive, and it has more and more influence on the war form and military revolution. The major military countries in the world have begun to research, develop, purchase and apply large UAS, which are mainly used in target indication, military mapping, battlefield reconnaissance, target surveillance, low speed or fixed target strike, damage assessment, communication relay, electronic warfare, information attacks, targeted killings and so on.[1]

MALE UAS is a kind of power-driven and reusable flight system. Due to UAS needs to be reused, it needs corresponding support system. UAS are widely used and frequently used in warfare, which requires UAS to ensure sufficient sorties, so we need to have a standardized and effective comprehensive security system.

Due to the different equipment characteristics and use modes between UAV and traditional aviation products, the traditional aviation integrated logistical support system can not be fully applicable to UAS. Therefore, this paper studies and constructs an integrated logistical support system for MALE UAS.

2. Composition of UAS
The UAS is composed of UAV, Measurement and Control and Information Transmission Subsystem, Mission Load Subsystem and Integrated Support Subsystem, as shown in figure 1.
2.1. **UAV**

UAV is an important part of the UAS. It is the basic platform for realizing the tactical and technical requirements of the system. It is used to carry the airborne equipment of Measurement and Control and Information Transmission Subsystem and various mission loads equipment.

2.2. **Measurement and control and information transmission subsystem**

Measurement and control and information transmission subsystem mainly completes the real-time transmission of UAS remote control, telemetry and reconnaissance information. It consists of Ground Control Station (GCS), Ground Data Terminal (GDT) and Airborne Data Terminal (ADT).

2.3. **Mission load subsystem**

UAV can mount and replace a variety of reconnaissance loads and weapon loads, including EO/IR, radar, communication reconnaissance load, aeromagnetic load, missile, bomb and other types of loads.

2.4. **Integrated support subsystem**

The Integrated Support Subsystem is a comprehensive support system to ensure the normal use and successful mission of the above three subsystems, and to provide support for the daily use, maintenance, spare parts supply, logistics management of UAS. This part is also the focus of this paper.

3. **Support characteristics of UAS**

According to the composition of UAS, we can see the difference between UAV and traditional aircraft, and its integrated support system cannot copy to the UAV completely. According to the system composition, operation characteristics and equipment characteristics of UAV, the support characteristics of UAS are analysed as follows:

3.1. **The composition of UAS is complex.**

According to the composition of the above-mentioned UAS, the UAS is more complex than that of the traditional aircraft, and the collaborative work between subsystems has high requirements. On the one hand, due to no pilots on the UAV, the information connection, information control and information collection between computers on aircraft platforms are more complicated. More functions of condition monitoring, fault diagnosis, automatic flight, autonomous judgment and autonomous decision-making are added to the UAV, which makes the UAV more automated, intelligent and autonomous[2]; on the other hand, the GCS belongs to the large-scale ground electronic system and remotely operates the UAV which has powerful function, advanced technology and complex structure. Therefore, UAS
covers many technical fields such as control, communication, command and control, and technology integration is more complex.

3.2. Distributed deployment of ground stations
In the deployment of UAS, not all ground stations are placed in the same site, but distributed deployment because of the need of mission. For example, the US Air Force Predator completes the UAV take-off and landing control at the front base through the take-off and landing control station and line-of-sight link. After take-off, the UAV link is established by the remote control station in the U.S. mainland and SATCOM, and the UAV mission is completed by the local mission commander, pilot and payload operator. For UAVs, flexible deployment and transshipment are needed in different bases according to operational tasks. Therefore, UAS has strong characteristics of distributed deployment and flexible configuration in operation and deployment.

3.3. Flexible replacement of mission load
According to the diversity of UAV mission requirements, UAV mounted mission loads can be flexibly changed, such as EO/IR, SAR, communication load, mapping camera, geomagnetic probe and other loads. Therefore, in operation, the ground station will configure and use different ground software to operate the load; in support, all kinds of load support equipment, support tools, spare parts, consumables, human resources, technical manuals should be complete.

3.4. High requirement of synergy ability
On the one hand, any link of UAS has malfunction, which will destroy the system work between air and ground, and lead to mission failure. Therefore, when UAV carries out its mission, the UAV in the air and the station on the ground need to cooperate highly with each other. On the other hand, when maintaining and repair the UAS, it needs aircrew and ground crew. The two groups of members work together in fault detection, fault detection, system testing, maintenance and repair, so they need a high degree of collaboration between personnel.

4. Planning of integrated logistical support system for UAS
In order to ensure the effective use of UAS, the integrated support system of UAS is to implement planning, organizing, commanding, controlling and coordinating management activities in all aspects of UAS support by means of modern information technology and management technology.

4.1. Top-level design of integrated support system for UAS
Integrated support system is a complex system with clear operation and mission. Its fundamental mission is to ensure and maintain the capability of UAS to carry out operation and training tasks. Specifically, in order to meet the needs of different support tasks, the integrated support system of UAS is an organic whole with the intersection and integration of various support activities, which has certain functions and interrelated support elements, according to the UAS support rules and support principles.[3]

The Integrated support system consists of support organization, support activities, support resources, support process, support management. Support activities, support organizations and support resources are the basis of support process. Support organizations are the foundation of site, support resources are the basis of resources, and support activities are the basis of work. Support management is a management activity based on the support process, which aims to ensure the effective control and operation of the support system, as shown in figure 2. Therefore, the purpose of this paper is to describe comprehensively the static structure composition relationship and dynamic system operation behavior of the support system.[4]
4.2. Support organization for UAS
Support organization refers to the establishment of equipment support organizations. The support organization is composed of the support sites, which are the places to complete the support activities. The support organization of UAS can be divided into two levels according to the level of maintenance organization: depot level (D-level) and organization level (O-level), as shown in figure 3.

O-level support organizations consist of UAS operators and maintenance personnel of their affiliated units. They carry out operation and maintenance support, and only complete short-term and simple support work. They generally undertake the operation of UAV support activities and equipment replacement and maintenance activities, which is the forefront of UAV mission and maintenance support. O-level support organizations mainly include runway, hangar, ground station, ammunition room, spare parts storehouse, maintenance room, tool room, fuel station, weather station, command hall and other places.

D-level support organizations have higher repairing capacity, undertake system overhaul and repair of large parts, spare parts manufacturing and support work that basic level cannot complete, mainly including maintenance workshop, warehouse, engine overhaul workshop and other places, as shown in figure 4.
Different from traditional aircraft, ground station is an important part of UAS, and its deployment location needs to be considered. Generally, it requires good visibility, stable power supply and so on. Ground stations can be deployed at fixed front-line bases or distributed, and multiple ground stations can be deployed at different front-line locations.

4.3. Support resources
Support resources are the material basis for UAS operation and maintenance, including support facilities, support equipment, support tools, manpower, spare parts, consumables and technical manuals, as shown in figure 5.

Support facilities are permanent and semi-permanent buildings and supporting equipment needed for the operation and maintenance of UAS, such as hangars, factory buildings, cranes, tractors and refueling trucks. In order to ensure the uninterrupted power supply of the ground station in the course of the mission, besides the UPS configuration of the ground station itself, it is necessary to provide generators for the ground station.

Support equipment is all the equipment (mobile and fixed) needed for the operation and maintenance of the system, such as test equipment, maintenance equipment, transport equipment, calibration equipment, test equipment, etc.
Support tools are all the tools needed for system operation and maintenance, such as general tools, special tools and equipment cables.

Manpower is the number of personnel needed for the maintenance of the system and the technical level of professional aircraft. The manpower of UAS is mainly divided into operation crew and maintenance crew. Operation crew is also divided into ground crew and air crew. The ground crew mainly supports the traction and release of UAV, and the air crew mainly carries out tasks in the ground station. Maintenance crew can be divided into mechanical technicians, avionics technicians, weapons technicians and so on.

Spare parts and consumables are replaceable parts and consumables for system maintenance. Spare parts include airborne spare parts, ground station spare parts, payload spare parts and support equipment spare parts. Consumables include rubber, liquid, standard spare parts and so on.

Technical manuals are the manuals needed for the operation and maintenance of the system. It can be divided into technical, operational and maintenance manuals according to categories.

4.4. Support function
Support function refers to the function that the support system needs to complete, mainly including the operation support function and maintenance support function, as shown in figure 6.

The operation support functions means that when equipment is stored, transported and used, the support system can provide corresponding support functions to ensure that equipment can be used at any time, including pre-flight inspection, post-flight inspection and re-fly inspection.

Maintenance support function is that when equipment fails, the support system can provide maintenance function for the malfunctioning equipment to maintain and restore the equipment in good technical condition, mainly including corrective maintenance and preventive maintenance. Among them, corrective maintenance can be divided into replacement maintenance, direct maintenance and fault isolation. Preventive maintenance can be divided into engine hour maintenance, flight hour maintenance, sortie maintenance and calendar time maintenance according to maintenance type.

Figure 6. Composition of support function.

4.5. Support process
Support process refers to the process of ensuring the UAS can normally perform tasks, including the operation support process, maintenance support process and supply support process, as shown in figure 7.

Mission process is the core of operating UAS. Tasks mainly include mission type, mission area, mission time and other requirements. According to the mission type, it can be divided into two kinds: one is strike mission, which has fixed-point reconnaissance and clearance mission with clear information about the precise location or specific scope of the target before the mission is executed; the other is reconnaissance mission, which can be used for wide-area reconnaissance mission in areas
of potential high-value target activity. The two tasks can be combined and converted in real time. After defining the mission, choose the UAS that can carry out the mission, including selecting the UAV and ground station, take off the UAV after completing the pre-flight support, carrying out reconnaissance or strike mission, and landing back to the hangar after the mission.

Operation support process refers to pre-flight support and post-flight support. Pre-flight support carries out flight path planning according to mission content, chooses payload or mounted weapons according to mission type, fills fuel according to mission time, and carries out pre-flight inspection and ground station preparation. Post-flight support mainly carries out post-flight inspection, unload weapons and withdraw the ground station.

![Figure 7. Schematic diagram of support process.](image)

Maintenance support process refers to UAV cannot be used normally, there are two situations: first, UAS has a fault, replacing the LRU at the O-level, fault LRU is sent to the D-level for repair; the other is preventive maintenance, also known as periodic inspection, when the operation of UAV accumulates to a certain engine hours, flight hours, sorties or calendar times need to be maintained accordingly.[5]

Supply support process refers to the process of supplying spare parts and consumables for UAV maintenance in time. O-level warehouse supplies spare parts and consumables for direct repair and D-level warehouse. D-level warehouse provides spare parts and consumables for replacement and maintenance at the O-level.

4.6. Support management
Support management is a series of management processes on the basis of support organization, support resources, support activities and support process, which makes the whole support system can be effectively implemented, mainly including: support record, maintenance management, quality control, data analysis, inventory management, organizational structure, fund management, etc., as shown in figure 8.

Support records refer to the support data generated during the operation and maintenance of UAS, mainly including UAV matching tables, flight confirmation records, flight data, flight sorties statistics, maintenance records, power-on time records, engine hours records, transport records, etc. Support records can effectively monitor the status of every link of UAV's daily use, so that every work can be recorded and traceable.

Maintenance management is divided into failure maintenance management and preventive maintenance management. Failure maintenance management records the replacement or direct maintenance of UAS due to failure. Preventive maintenance management refers to reminding maintenance personnel to carry out corresponding maintenance operations when UAV accumulates to a specific fixed inspection period.
Quality control means that the quality responsible department should supervise and manage the maintenance of UAS, coordinate the relevant resources, provide corresponding technical support, and complete the relevant support activities on time and according to the requirements.

![Support Management Diagram]

**Figure 8.** Composition of support management.

Data analysis refers to the status analysis of flight data according to the system or equipment, timely attention to the health status of UAS, through the analysis of data, we can locate faults and find potential faults in time.

The organizational structure refers to all the departments responsible for the operation, maintenance, management and supervision of UAS. Each department has a clear division of responsibilities and cooperates to complete the work of UAS.

Funds management refers to the cost management generated in the life cycle of UAS, which mainly includes manpower cost, procurement cost, maintenance cost, supply cost and so on.

5. **Conclusion**

Firstly, this paper describes the four major components of UAS, analyses and refines the four support characteristics of UAS, which are complex composition, distributed deployment of ground station, flexible change of mission payload and high requirement of collaborative ability. Based on the above, an integrated support system of UAS is established, and the several key elements of support system is described: support organization, support resources, support function, support process and support management. Through the above research, a comprehensive support system of UAS with static structure and dynamic system operation is formed, which can effectively and reliably support the operation and maintenance of UAS.

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