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DESIGN OF A HYBRID VTOL LOGISTICS UAV SYSTEM INTEGRATED INTO CIVIL AVIATION AIR TRAFFIC CONTROL SYSTEM

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Abstract

The three-level aviation logistics system based on the trunk line, branch line, and terminal constructs the air rapid network blueprint of the logistics industry. The branch level needs the available unmanned aerial vehicles (UAV) and meets the leading indicators of carrying capacity, operation cost, and efficiency. With the continuous improvement of UAV platform technology, integrated airspace operation management has become the focus. This paper introduces the three-level aviation logistics system structure and describes the vertical take-off and landing (VTOL) branch line logistics UAV and its application scenarios. A hybrid VTOL UAV system scheme integrated into the civil aviation air traffic control (ATC) system are presented.

Keywords: aviation logistics, air traffic control, integrated airspace, logistics UAV

1. Introduction

With the importance and advantages of aviation logistics becoming more and more prominent, logistics operators have proposed a three-level aviation logistics system to build the air network frame of the logistics industry[1]. Branch line aviation logistics is an essential link of the three-level aviation logistics system. The branch line VTOL logistics UAV is the most promising to be commercialized in advance because of its adaptability to unique scenarios. At the same time, the application of branch line logistics UAV will inevitably enter the integrated airspace, bringing new topics to the transportation system.

1.1 Three-level aviation logistics system

Figure 1 – Three-level aviation logistics system

The three-level air logistics, as shown in figure1, upgrades the traditional air logistics to an end-to-end complete air transport capacity, which is composed of a trunk line, branch line, and terminal, connecting to complete the distributing of goods. The trunk line still uses manned civil aviation

cargo planes to carry out cross-region logistics transportation. The range is more than 800km, usually about 1500km, and the cargo carrying capacity is 20 to 60tons. The branch line needs medium and large logistics UAVs to carry out logistics transportation tasks between cities in one region. The range is about 300 to 800km, and the cargo carrying capacity is mostly 0.2 to 2tons. Small logistics UAVs are used at the terminal to complete the “last kilometer” of distribution. The range is within 50km, and the cargo is between 5 to 50kg[1].

At present, the trunk cargo aircraft has thousands of huge fleets and mature operation mechanisms. Many companies and manufacturers are developing terminal logistics UAV, including Amazon, DHL, UPS, SF, JD, whose transportation platforms and operation modes are developing rapidly. However, the key to the three-level logistics structure lies in the branch link. In addition to the development of fixed-wing branch logistics UAV and VTOL branch logistics UAV, the UAV of above magnitude can no longer be limited operation in the isolated airspace[2]. The corresponding ATC system should be discussed.

1.2 Scenarios of branch line VTOL logistics

Branch line VTOL logistics UAV is a kind of logistics transportation platform used in unique scenarios as VTOL UAV has the ability of vertical take-off and landing, it has unique technical advantages in the logistics scene of islands, mountains, and other areas where the ground take-off and landing facilities are challenging to build. Moreover, in these scenarios, most of the logistics routes are in remote areas, and there are few cities with a concentrated population. In this way, it has lower operational risk and a lower the threshold for airworthiness and commercial operation

Figure 2 – VTOL logistics UAV in mountain and island scenes[3]

VTOL logistics UAV has obvious efficiency advantages comparing with vehicle and ship transportation in mountain or island scenes, as shown in figure2. In these scenarios, the VTOL logistics UAV scheme can offset the traditional logistics’ economic advantages whose benefits are from faster transportation speed, driver cost reduction, industrial-grade supply chain development, and composite molding process innovation. More importantly, many goods with substantial timeliness requirements, including fresh food, drugs, emergency supplies, can only provide customers with satisfactory service through the VTOL logistics program.

1.3 Integrated airspace

Since drones in the industry are now widely used, the current way to limit UAV operation in isolated airspace cannot meet the needs of UAV operators. Therefore, UAVs are developing towards the direction of mixed operation with manned aviation. The mixed operation airspace of unmanned and manned aviation is the integrated airspace[4]. International Civil Aviation Organization (ICAO) divides the development of UAV into three parts: segregation, accommodation, and integration, to integrated with manned aviation gradually.

Going out of the isolated airspace includes the following three problems: Firstly, it is necessary to have an ATC system to support civil airliner and UAVs. The UAV needs to adapt to the existing system or the ICAO to upgrade the existing system. Secondly, UAV must adopt effective measures to improve their safety. The safety of unmanned vehicles should not be lower than the similar standards of manned aircraft, nor follow higher standards because of technical permission. This principle is called the equivalent level of safety (ELOS)[5]. Thirdly, the workload assessment of controllers is also an essential part of the integrated airspace operation[6,7]. Current research shows that when UAVs enter the integrated airspace, the workload of controllers will increase by about 20% compared with managing only manned aircraft.

2. VTOL logistics UAV ATC system framework

Although VTOL logistics UAV is a kind of branch line platform, compared with logistics UAV with larger freight capacity (more than 1000kg), it has lower flight altitude and rarely intersects with civil aviation routes and minor risk of collision. The Mode s transponder and ADS-B provide ID identification, four-dimensional position, track angle, route, conflict alarm, and other information for UAV[8]. Controllers can monitor UAV in real-time. Other sensors are selected according to the needs, such as a traffic collision avoidance system(TCAS) as the preferred device to realize the perception and avoidance of cooperative targets, EO/IR to realize the detection of non-cooperative targets, the terrain awareness and warning system (TAWS) to realize the detection of ground obstacles.

Accordingly, the increase of workload brought by VTOL logistics UAV is limited. Most of its flight routes are in isolated airspace, and it is not necessary to enter the airport in terms of take-off and landing when entering the islands or mountainous areas for cargo distribution. The VTOL logistics UAV uses a relatively easy take-off and landing site, which is why the above topics are discussed for VTOL logistics UAV. At present, the VTOL platform can follow the existing civil aviation management system as soon as possible and has the opportunity to realize commercial operation first. For market demand and operating environment, this is a suitable solution.

2.1 ATC system supporting logistics UAV

A set of aviation management systems that can support both civil aviation aircraft and UAV is the key for VTOL logistics UAV to enter the civil aviation air traffic control system. In terms of reliability derived from technology, it is the best choice that this aviation management system can continue the previous structure, at least limit the change proportion based on the basis of the original structure. It must be considered that the construction of the system needs much financial support, and the new system should try to avoid bringing unforeseen risks and burdens to all aspects.

As shown in figure3, a scheme of VTOL logistics UAV entering the civil aviation air traffic management system is proposed, in which the red part is the structure of the existing civil aviation air traffic management system, and these contents are completely reserved in this scheme. The yellow part in the figure is the supplementary aviation management module in the operation process for UAV.

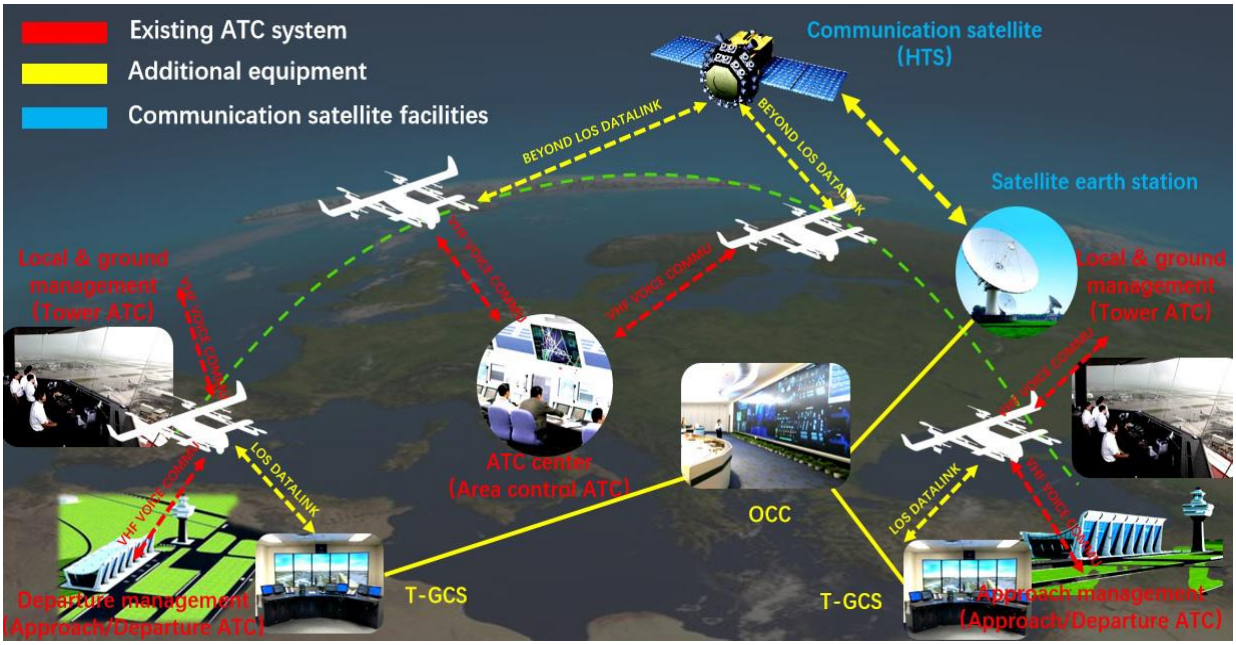

Figure 3 – ATC system supporting logistics UAV

Referring to the original ATC structure, the yellow part is used to build the real-time communication between controllers and UAV pilots. Obviously, in a single flight, the UAV pilots talking with the controllers are different in 3 flight phases. These pilots are not on the UAV because there is no cockpit. Instead, a pilot in/near the airport at the departure airport and the landing airport, stays in the terminal area ground control station (T-GCS). The pilot on the route is in the operation control center (OCC) of the UAV operator.

In fact, in most cases, VTOL branch line logistics UAV does not need to activate this set of functions. The VTOL will likely take off from a leveled open space beside the town. At this time, the pilot is a courier of the logistics station in the town.

2.2 Additional equipment

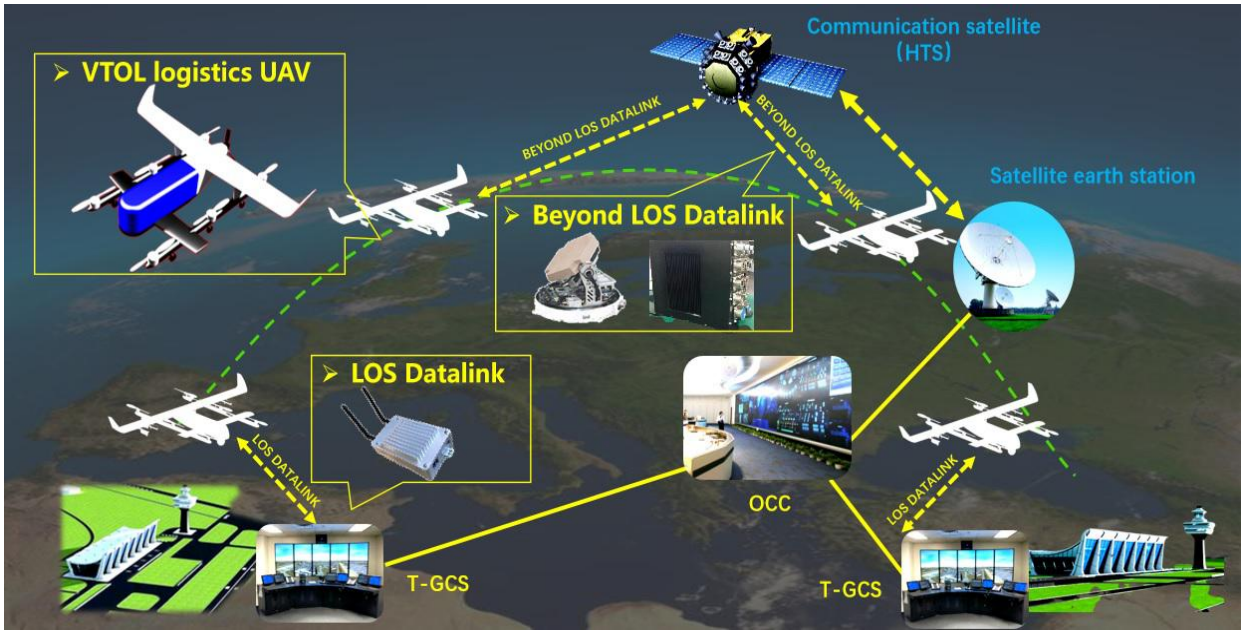

Figure 4 – Additional equipment for UAV entering integrated airspace

In the take-off and landing terminal area, the operator sets up a T-GCS to communicate with the UAV through the line of sight (LOS) data link. Pilots in the T-GCS can control and monitor the UAV remotely or make voice conversations with the approach/departure ATC controller, as shown in figure4.

Operators carry out real-time remote monitoring and control for all VTOL branch logistics UAV

nodes in operation, and the collection point of all data is the OCC. The UAV connects with OCC through the beyond LOS data link supported by the communication satellites. The UAV pilots in OCC can control the UAV and make voice dialogues with region ATC controllers by the connection.

Other options for the configuration of additional equipment include setting 5G communication base stations in terminal areas and along routes, and combining with the ground network to realize the remote control and the dialogue functions[9]. However, for the early operation of VTOL logistics UAV, the currently selected additional equipment scheme has advantages in economy and technology maturity.

3. VTOL branch line logistics UAV

Many institutes and companies are currently developing VTOL UAVs. However, as a branch logistics transportation platform with a gross weight of more than 400kg, VTOL UAV needs to meet specific technical requirements while being equipped with additional equipment for airline operations. Including sufficient cargo storage and transportation space, stringent economic requirements and easy maintenance and operation features.

3.1 Key technology

In order to meet the requirements of vertical take-off and landing, low operation cost, high reliability and being integrated into the civil aviation system, the critical techniques of system design are performed as follows:

- VTOL UAV general design technology, to solve the vertical power unit arrangement, center of gravity control for cargo loading and layout optimization design, to match the design inputs;
- Advanced lightweight structure design technology to solve high structure efficiency, long fatigue life, and low-cost structure and material design, to satisfy the requirement of weight, cost, and life comprehensively;
- High reliability of automatic adaptive flight control technology, to solve the transition flight control, control law reconstruction at-fault state, adaptive and fault-tolerant control reliability and redundancy control design, to ensure the safety during the entire flight envelope;
- Oil/electric hybrid power system design and energy management technology to solve the overall power design, electrical energy system status, and safety monitoring.

3.2 Technical proposal of UAV

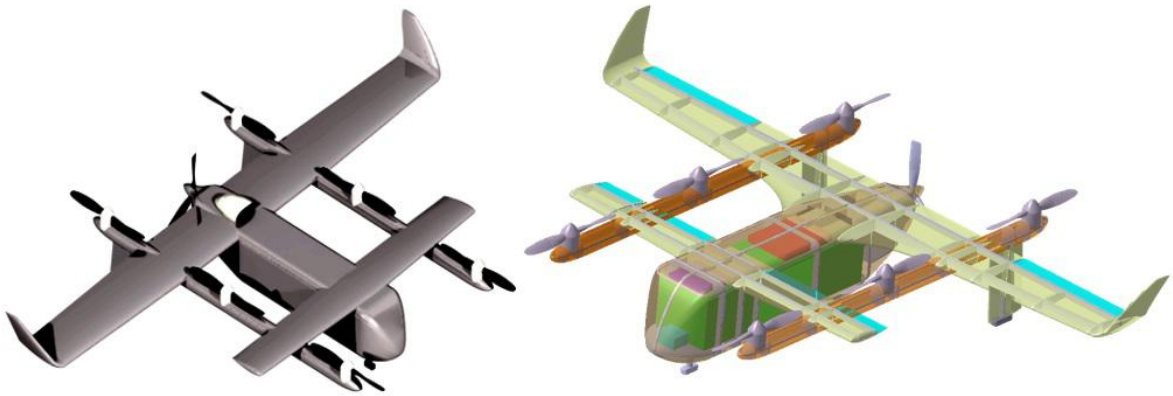

Figure 5 – Hybrid VTOL logistics UAV system

UAV adopts the design of canard layout, upper-single wing, double booms supporting six rotors. High-voltage lithium batteries drive rotors, while cruising power uses a piston fuel engine. Figure 5 shows the general configuration and arrangement of a VTOL branch line logistics UAV.

The logistics UAV system has the following advantages:

- Low costs, no need for airports and pilots, low cost of materials and structural design, low-cost manufacturing process, and adapt to the current air traffic system, ensuring the low cost of operation and maintenance;
- High efficiency, VTOL, and higher cruising speed ensures the realization of the air flying straight, shorten the distance, speed, can quickly reach;
- Higher safety, with the ability to safe landing in case of one rotor failure;
- All terrains' adaptability, vertical take-off and landing, only need a small area of flat ground.

4. Summary

The development of aviation logistics can bring people faster and more convenient logistics services. VTOL branch line logistics scheme also provides more convenient logistics options for remote mountainous areas and islands residents. This new approach can help these residents sell more different kinds of fresh specialties in exchange for the necessary living expenses, and at the same time obtain better living and medical supplies. This paper proposes a civil aviation operation architecture based on VTOL branch line logistics UAV and puts forward some views on communication and delivery platforms.

This paper provides some ideas on the design techniques for future UAVs operating in the integrated airspace, especially for VTOL logistics UAVs. At the same time, it can be used to build air traffic management systems that takes UAV management into account. The VTOL logistics unmanned aerial system, including the additional operational equipments, will be validated through flight test.

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6. Copyright Statement

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