Airport Collaborative Decision-Making in Single Pilot Operations of Commercial Aircraft

Yue Luo[1], Miao Wang[1](✉), Yong Chen[1,2], Kelin Zhong[3], and Guoqing Wang[1]

[1] Shanghai Jiao Tong University, Shanghai, China
{luoyue,miaowang,wang_guoqing}@sjtu.edu.cn, chenyong@comac.cc
[2] Commercial Aircraft Corporation of China, Shanghai, China
[3] COMAC Shanghai Aircraft Design and Research Institute, Shanghai, China
zhongkelin@comac.cc

Abstract. As an important direction of modern aviation technology, single pilot operations (SPO) of commercial aircraft puts forward a strong demand for airport capability and efficiency, so it is necessary to establish the airport collaborative decision-making (A-CDM) capability under SPO. Based on the system architecture of A-CDM under current dual-pilot operation mode, this paper analyzes the core information sharing mechanism and milestone method. Then, based on the characteristics of SPO, SPO-A-CDM is proposed. Finally, a co-simulation platform of flight scenario and system model is constructed, and a typical scenario – fixed-point deicing is taken as an example to carry out the model-based simulation analysis of SPO-A-CDM.

Keywords: Airport Collaborative Decision-making · Single Pilot Operations · Fixed-point Deicing · Commercial Aircraft

1 Introduction

With the rapid development of civil aviation, the scale and business volume of airports are also expanding day by day. Many large airports are faced with limited number of resources such as runways, parking spaces and surface support facilities, and low rate of intelligent resource allocation, which leads to low operating efficiency and poor collaborative decision-making ability [1]. In order to solve the above problems, airport collaborative decision-making (A-CDM) was proposed, aiming at making the airport, ground handling, air traffic control (ATC), airline and aircraft participate in collaborative decision-making through information sharing, so as to optimize the utilization rate of airport resources, reduce flight delays and improve the operation efficiency of the airport [2, 3].

Single pilot operations (SPO) is one of the core technologies for the new generation of commercial aircraft, which is of great significance in the aspects of operation economy and flight safety [4, 5]. In SPO, there is only one pilot on board, who has limited cognition and perception, and requires collaborative interaction with the ground to obtain a more comprehensive situational awareness. According to the requirements of airport

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development in the Aviation System Block Upgrade (ASBU) proposed by International Civil Aviation Organization (ICAO), it is necessary to establish the A-CDM capability under SPO.

Therefore, this paper first introduces the system architecture of A-CDM under the current dual-pilot operation mode, and analyzes the core information sharing mechanism and milestone method. Then, based on the characteristics of SPO, SPO-A-CDM is proposed. Finally, a co-simulation platform of flight scenario and system model is constructed, and a typical scenario – fixed-point deicing is taken as an example to carry out model-based simulation analysis of SPO-A-CDM.

2 A-CDM in Dual-Pilot Operation Mode

2.1 A-CDM System Architecture

Airport Collaborative Decision Making (A-CDM) is an operational mechanism led by the airport and jointly participated by aircraft, airline and Air Traffic Control (ATC), based on information sharing, guided by "improving the efficiency of surface operations", and centered on "collaborative decision making" [6, 7].

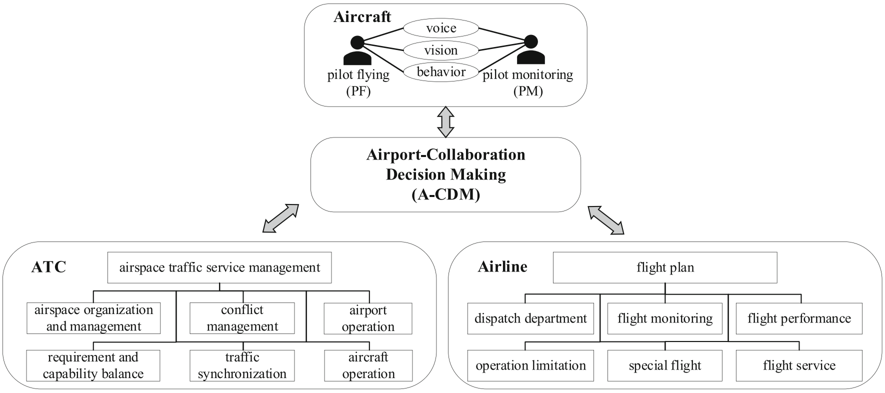

Fig. 1. System architecture of A-CDM.

As shown in Fig. 1, in the A-CDM system architecture, ATC is responsible for airspace traffic service management, including airspace organization and management, requirement and capability balance, conflict management, traffic synchronization, airport operation and aircraft operation; Airline is responsible for flight plan execution, including dispatch department, flight monitoring, flight performance, operation limitation, special flight and flight service. In the non-nominal flight, the PF and PM complete collaborative decision making through voice, vision and behavior and other face-to-face interactive ways. Ultimately, all parties can make a collaborative decision based on their own requirements, resulting in a favorable processing result that is beneficial to all parties involved.

2.2 Information Sharing

The prerequisite of collaboration is to solve the information interaction among all participants [8]. In A-CDM, real-time information sharing among air-ports, air traffic control, airlines and aircraft is the basis of collaborative decision-making. As shown in Fig. 2, all participants can perceive the common situation of airport and flight operation through the information sharing plat-form. Based on the shared information, the participating units can collaborate to make safer and more effective decision-making solutions and optimize their own decisions, which helps the airport effectively optimize the forecast of the overall operating situation, improve the operating efficiency, and then improves the accuracy of prediction and flight frequencies for aviation management.

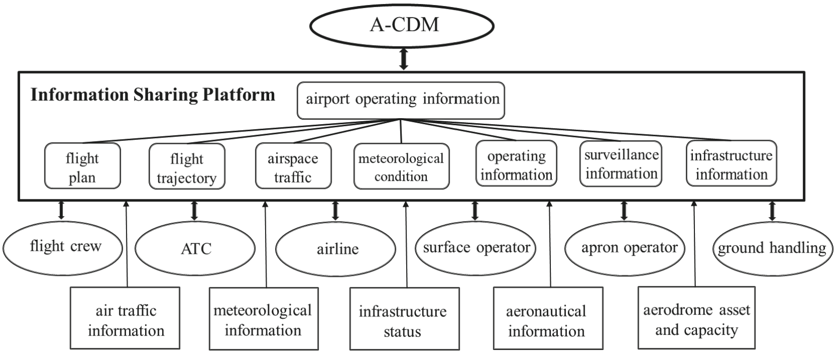

Fig. 2. Information sharing in A-CDM.

After the information is shared, the interests and demands of all parties can be further analyzed. For example, the resident airlines want their flights to be launched according to the schedule as far as possible to reduce delays; ATC expects the number of flights to be adjusted to the minimum, reducing the average takeoff and landing time; The airport hopes to improve the utilization rate of resources such as parking place and corridor bridge as much as possible, so as to obtain a larger throughput. Based on the requirements of all par-ties, a compromise that satisfies all parties can be reached through collaborative decision-making.

2.3 Milestone Method

Milestone events are significant events that occur during flight planning and flight operations. Completed milestone events will affect the decision-making process of the subsequent event, which will influence subsequent flight operations and accurate prediction of subsequent events. Defining mile-stones and tracking them helps improve each participating unit's awareness of flight situations, as well as anticipate potential flight delays and develop response plans in a timely manner. Figure 3 shows the key milestones of flight operations, which covers the entire airport operation from inbound, turnaround and outbound [9].

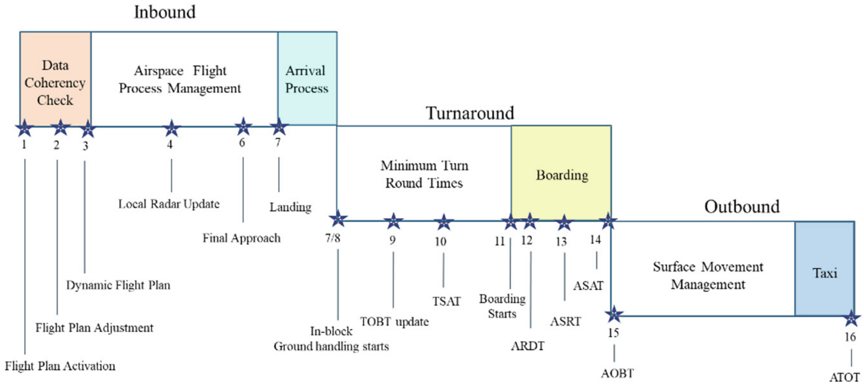

Fig. 3. Milestone method in A-CDM.

3 A-CDM in Single Pilot Operations Mode

3.1 Single Pilot Operations Mode

Single pilot operations (SPO) is a piloting mode in which there is only one pilot in the cockpit. To avoid excessive workload of the single pilot, more advanced airborne intelligent system and ground support are introduced, as shown in Fig. 4. The airborne intelligent system is divided into automatic, autonomous and intelligent modes. In the nominal flight, the airborne intelligent system works in the automatic mode and runs according to the preset automatic program. In the non-nominal flight, the airborne intelligent system works in the autonomous mode, which performs flight optimization processing based on input conditions and external environment. In the authorized airspace, the airborne intelligent system works in the intelligent mode. It can provide suggestions and support based on reasoning, learning, and mining, as a supplement to the single pilot's cognition.

The ground support system includes ground simulation system and a ground operator who is hired part-time by the airline dispatcher. The ground simulation system can visualize the received flight status for the convenience of the ground operator. The ground operator is responsible for monitoring the flight, interacting with ATC and, in non-nominal cases, coordinating with the single pilot on board. As a result, the decision-making mode of the cockpit has changed from the original face-to-face communication to human-machine collaborative decision-making and air-ground collaborative decision-making.

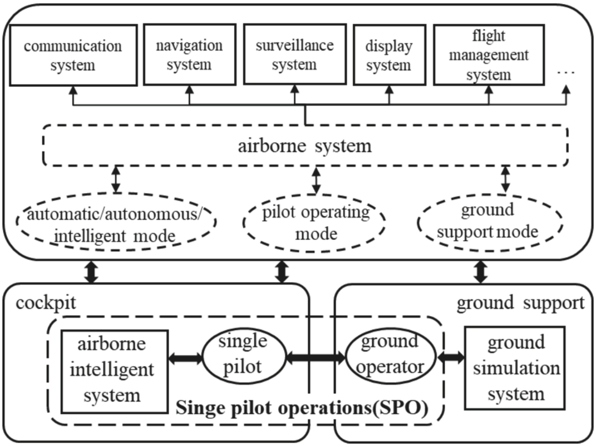

Fig. 4. Single pilot operations (SPO) mode.

3.2 Decision Process Organization of Single Pilot Operation

In SPO, the pilot on board makes flight decisions based on flight plan compliance, airspace environment adaptability, flight performance feasibility, air-craft/system capability availability, and flight safety effectiveness [10]. In different situations, the airborne intelligent system works in different modes to provide decision support for the single pilot on board and the operator on the ground.

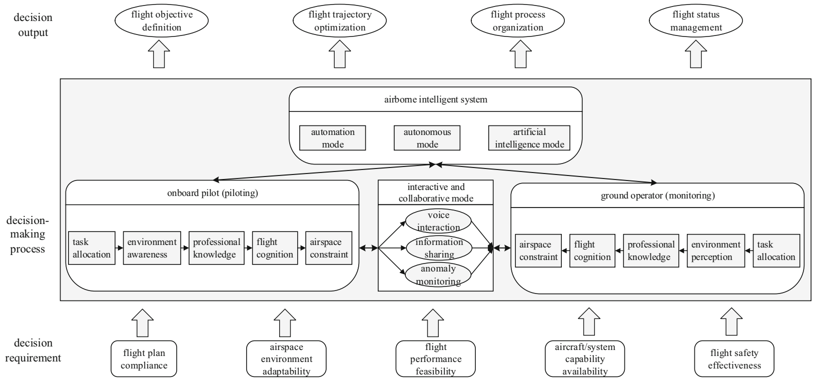

Fig. 5. Decision process organization of SPO.

Based on different task allocation, environmental awareness, professional knowledge, flight cognition and airspace constraint, the onboard pilot and the ground operator finally complete air-ground collaborative decision-making through voice interaction, information sharing, and anomaly monitoring, as shown in Fig. 5.

3.3 SPO-A-CDM

Due to the change of decision-making mode in SPO, SPO-A-CDM requires intelligent systems, including airborne intelligent system and ground intelligent system, to support human-machine collaborative decision-making and air-ground collaborative decision-making, so as to ensure flight safety. In addition, in view of the difficulty of information sharing and interaction existing in A-CDM, an information sharing platform need to be established to conduct intelligent processing and distribution of shared information, and to support intelligent decision making. The system architecture of SPO-A-CDM is shown in Fig. 6.

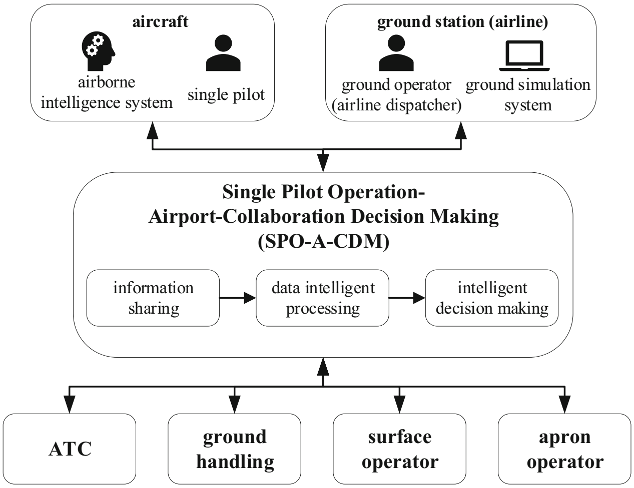

Fig. 6. The system architecture of SPO-A-CDM.

1) Intelligent system support
   SPO-A-CDM cannot be separated from intelligent systems, including air-borne intelligent system and ground intelligent systems. Among them, the air-borne intelligent system can be divided into automatic, autonomous, and intelligent modes based on different situations. In intelligent mode, it can pro-vide solutions to pilots to support flight decisions based on reasoning, learning, and mining. The ground intelligent system relies on mobile Internet, geo-graphic information system (GIS), big data mining and other technologies to realize real-time perception of flight operation and vehicle activities, and intelligent allocation of ground resources to support airport collaborative decision-making [11].
2) Information sharing and intelligent processing
   In SPO, in order to reduce the workload of the single pilot, many tasks will be handed over to the intelligent system and the ground. The consistency of flight and surface operating information obtained by all parties is the premise of collaborative decision-making, and information sharing is in fact the “glue” that ties these partners together. For airports, gate location, taxiing time from gate location to runway, expected start

time and length of deicing time should be provided. For ground handling, target guaranteed completion time, minimum layover time, flight plan and departure priority should be provided. For airlines, scheduling data should be provided. For ATC, estimated departure time, actual departure time, area control time, terminal control time, landing time of the flight, etc. should be provided. In addition, the aircraft needs to synchronize flight status to the ground station to support coordination and interaction between the ground operator and other parties.

Cloud computing is used to efficiently process and transmit the information of all parties through the information sharing platform to support the collaborative decision-making of all parties.

4 Modelling and Analysis

4.1 Simulation Platform

Firstly, the airport surface operation scenario is designed and the surface operating process is modelled through the scenario simulation software Prepar3D. Then, the internal logic of the surface operation is modelled through the system modelling software Magicdraw. The system architecture, operating organization, and information sharing of SPO-A-CDM will be modelled. A synchronization component between P3D and Magicdraw will be developed, with the flight scenario simulation module transmitting flight status information to the system model and the system model transmitting milestone trigger to the flight scenario simulation, thus controlling the operating process of the airport surface. Through the joint simulation of the flight scenario model and the system model, the analysis and verification of the SPO-A-CDM operational organization is completed. The simulation platform of SPO-A-CDM is shown as Fig. 7.

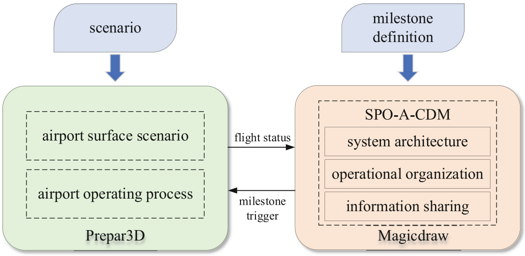

Fig. 7. The simulation platform of SPO-A-CDM.

4.2 Model-Based Simulation Analysis

In this section, a typical surface scenario – fixed-point deicing is taken as an example to carry out the model-based simulation analysis of SPO-A-CDM. At the beginning of the ice season, a deicing area is set up to provide deicing services for aircraft at a fixed location. In the event of ice and snow, after passengers have boarded the aircraft, the single pilot on board reports the ice buildup to the airline. Then, the ground operator applies to the airport for de-icing. The airport arranges the aircraft to proceed to the appropriate deicing area according to the progress of deicing. The ground operator receives the deicing information and synchronizes them with the airborne intelligent system. Then, the airborne intelligent system automatically loads the route and proceeds to the designated deicing area under the guidance of ATC. After de-icing, the ground operator applies to ATC for a taxi out, and then ATC issues a taxi clearance, the single pilot accepts the taxi clearance and starts taxiing [12].

Collaborative deicing under SPO-A-CDM involves interaction among the single piloted aircraft, the airline operation center, the ground operator, ATC and the airport. The information interaction model for collaborative deicing constructed through Magicdraw is shown in Fig. 8.

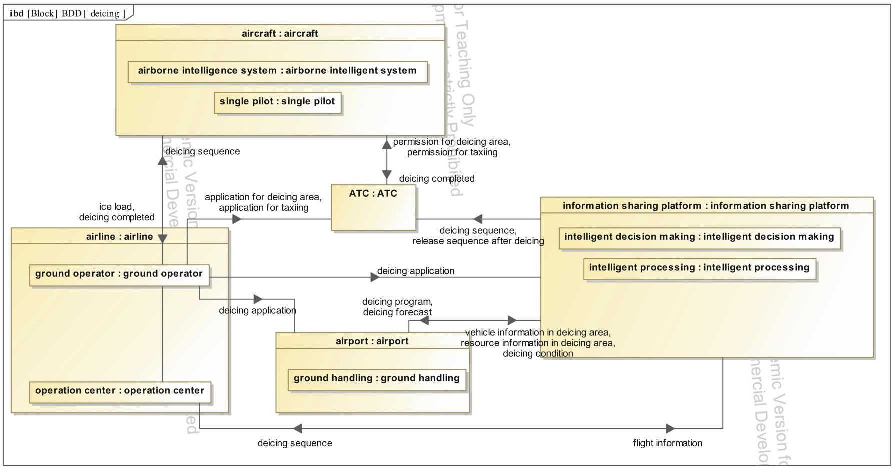

Fig. 8. The information interaction model for collaborative deicing.

The deicing process is combined with SPO-A-CDM to provide accurate flight information for deicing process through information sharing, ultimately facilitating deicing planning. By sharing deicing scheduling information, through intelligent processing and intelligent decision making, limited deicing resources can be planned and used in a rational manner to maximize the efficiency of deicing at the airport, enabling monitoring, scheduling and com-manding of deicing management, and optimizing the sequencing of flight departures to improve airport operating efficiency.

5 Conclusion

Based on the characteristics of SPO, SPO-A-CDM is proposed in this paper. Through the co-simulation platform of flight scenario and system model, model-based simulation analysis of SPO-A-CDM is carried out. By sharing in-formation, through intelligent processing and intelligent decision making, limited airport resources can be planned and used in a rational manner to maximize the efficiency of airport operation.

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