



ICAO

*International Civil Aviation Organization***The Third Meeting of Air Traffic Management
Automation System Task Force of APANPIRG
(ATMAS TF/3)**

Web-conference, 8 – 10 June 2022

Agenda Item 4: ATM Automation System Implementation by States

4.2 Integration with External Systems

**TECHNICAL RESEARCH ON SWIM-BASED INTEROPERABILITY FOR
ATM AUTOMATION SYSTEM**

(Present by China)

SUMMARY

This paper firstly introduces the technical scheme of SWIM-based interoperability for ATM automation systems. Then build a test platform to verify the feasibility. At last, it gives a summary and outlook.

1 BACKGROUND**Previous Research**

1.1 System Wide Information Management (SWIM) breaks the traditional point-to-point transmission topology and realizes real-time information sharing. ICAO has made SWIM an important part of Aviation System Block Upgrades (ASBU) in the sixth edition of the Global Air Navigation Plan (GANP).

1.2 In 2009, Europe planned the SWIM application roadmap and published the ED-133 document, which designed a scheme for the data sharing of Flight Object (FO) and the interoperability (IOP) mechanism of ATMAS.

1.3 At present, the interoperability between China's ATM Automation Systems (ATMAS) still adopts the message interaction method. In 2017, China began to try to apply SWIM on ATMAS, and cooperated with relevant manufacturers to carry out technical research work in two stages, and complete the two stages of scientific research in 2021.

Objective

1.4 The current scale of ATMAS in China is very large. Beijing, Shanghai, and Guangzhou are all utilized a centralized FDP, which provides fully consistent flight data and seamless interoperability. However, it also has the disadvantages of high maintenance difficulty and high flight data processing pressure.

1.5 In this study, we simulate the conversion of the current single system into multiple medium-sized systems operating independently, while maintaining a high level of flight data consistency and interoperability among the systems.

1.6 The purpose of this research is to use SWIM as a framework to achieve flight data sharing and efficient interoperability between multiple systems using the concepts of FO and IOP in the ED-133 document.

2 SWIM-BASED INTEROPERABILITY TECHNICAL SOLUTION

SWIM Architecture

2.1 The SWIM architecture proposed by ICAO is shown in Figure 1. Our study focuses on the Flight Information Exchange Model (FIXM). The technical solution includes the following parts:

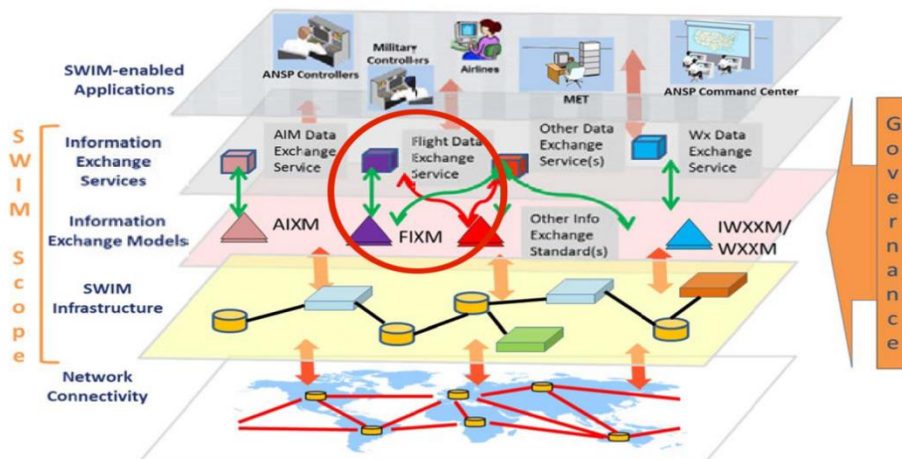


Fig.1 ICAO Doc10039 SWIM Architecture

- A SWIM node is added to each ATMAS as the SWIM infrastructure. A local FO database is stored in the SWIM node. These SWIM nodes are networked together by means of a Data Distribution Service (DDS) to share a unified flight object view with other ATMAS. Between the SWIM node and the FDP, a SWIM adaptor is added to connect the FDP to the SWIM network.

- The information exchange model adopts the FIXM data format to describe the FO in ED-133.

- At the information exchange service level, services such as subscription, publication, and modification requests for FO are provided to realize operations such as creation, modification, coordination, and handover of FO between ATMAS.

- As SWIM-enabled applications, the ATMAS have modified their existing FDP to complete the logical expression from internal flight data record (FDR) to FO. Various interoperability scenarios are realized through the information exchange service of SWIM flight data in the lower level.

- The concepts of IOP and participant roles from ED-133 are adopted to implement SWIM governance. As shown in Figure 2, IOP participants are divided into different functions:

- **Flight Data Manager / Publisher (FDMP):** the current control unit of the FO, has the authority to modify and publish;

- **Flight Data Contributor (FDC):** the follow-up control unit, has the authority to request changes to parts of the FO;
- **Flight Data User (FDU):** the ATMAS whose airspace will be penetrated by a flight in the future, the control area that the trajectory does not pass through or other ATMASs connected to SWIM, can subscribe to the flight data.

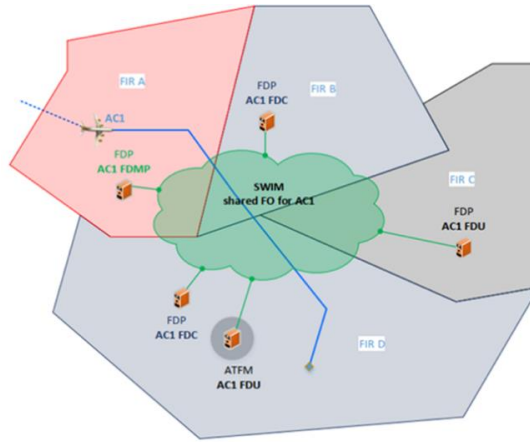


Fig.2 IOP Participant Roles

Interoperability Scenario Design

2.2 According to the operation requirements, it designs three interoperability scenarios. Interactions in homogeneous systems, heterogeneous systems, and degradation modes. Some basic interoperability processes are designed for each scenario, including creating a flight plan, FDMP modifying the plan, FDC requesting to modify the plan and FDMP executing the modification, handover, forced reception, etc. The effect of data sharing in each ATMAS and the conversion of IOP roles are observed when different interoperations occur.

➤ **Homogeneous Systems**

2.3 In contrast to the centralized flight plan processing system, the SWIM-based homogeneous system interoperability platform architecture is shown in Figure 3. ATMASs run in the same flight information region and have roughly the same offline configuration. FO shared among various ATMASs, adopts the data model with 13 data clusters recommended by ED-133.

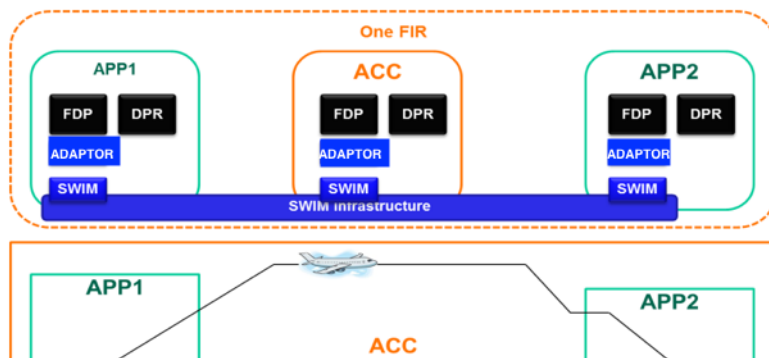


Fig.3 Homogeneous System Interoperability Platform Architecture

➤ **Heterogeneous Systems**

2.4 Due to the large deviation of offline data between heterogeneous systems, flight data processing is highly likely to be inconsistent, so the FO data model needs to be reconstructed to make communication more compatible. Here, the FIXM (version 4.2) extension package with strong scalability and versatility is used to replace the 13 data clusters in ED-133, whose format is shown in Figure 4.

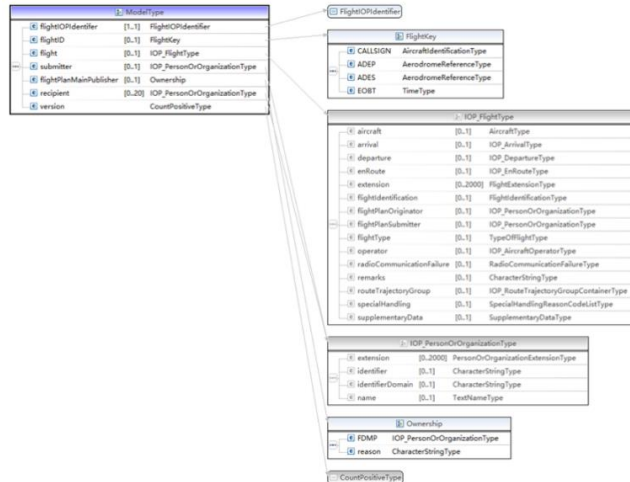


Fig.4 Universal FO Data Model

➤ **Degradation Modes**

2.5 Degradation is the disconnection of an ATMAS from the SWIM network. The degraded ATMAS still has complete flight plan data and can manage flights in the airspace autonomously. But interaction with other ATMASs needs to be switched to an alternate interface, such as the original AFTN or AIDC dedicated line. When the degraded ATMAS re-establishes the connection with SWIM, it needs to synchronize the flight data related to this airspace in SWIM, and publish the FO controlled by this ATMAS to the outside.

2.6 Role changes occur when the ATMAS is degraded and reconnected. Figure 5 and Table 1 show the logic of role calculation and data synchronization.

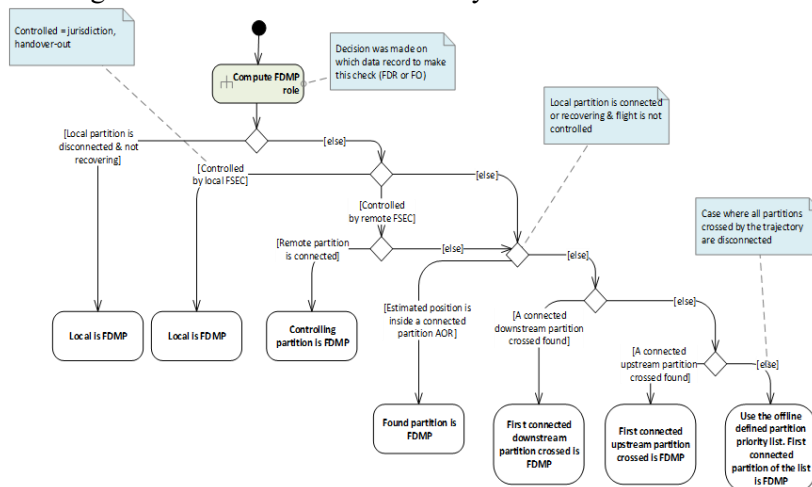


Fig.5 IOP Roles Calculation after Degradation

	Partition 1 (synchronising)		Partition 2 (Networked)	
	Before	After	Before	After
1	FDMP, jurisdiction	FDMP, jurisdiction	FDMP, not jurisdiction	FDC
2	FDMP, jurisdiction	FDMP, jurisdiction	FDMP, jurisdiction	FDC
3	FDMP, jurisdiction	FDC	FDMP, jurisdiction	FDMP, jurisdiction
4	FDMP, not jurisdiction	FDMP, not jurisdiction	FDMP, not jurisdiction	FDC
5	FDMP, not jurisdiction	FDC	FDMP, jurisdiction	FDMP, jurisdiction
6	FDMP, not jurisdiction	FDC	FDMP, not jurisdiction	FDMP, not jurisdiction
7	FDMP	FDMP	Unknown	FDC
8	FDMP	FDC	Unknown	FDMP

Table.1 FO Status during Synchronization

2.7 In addition, this study explores the implementation scheme of the master-standby system synchronization in IOP. It is achieved through the FO data item and IOP status, that is, the system name and the master-standby status are shared in SWIM, so that SWIM can sense. As long as the main ATMAS is connected to the SWIM node, it is online. The backup ATMAS is FDU, which only passively receives FO and does not send FO. When the main ATMAS is degraded, the backup ATMAS will not be upgraded to FDMP automatically, but will receive a reminder. You need to manually confirm the switchover.

3 TEST EFFECT

3.1 The test platform is composed of three SWIM-based ATMAS, including Shanghai Regional Management System (SHER), Shanghai Terminal System (PDER), and Hefei Terminal System (HFER). The first two are homogeneous systems, and Hefei is heterogeneous with them. Each system has an independent FDP, and is interconnected with other systems by accessing the network through SWIM adaptors.

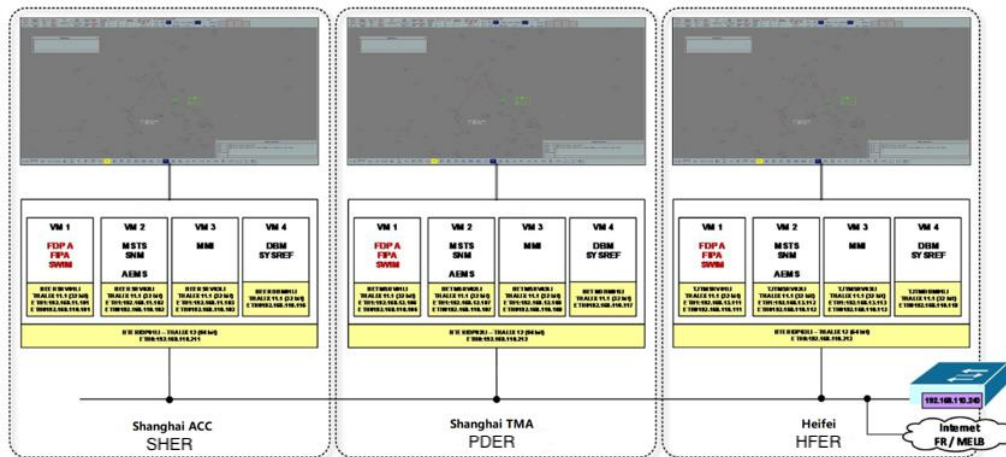


Fig.6 Test Platform Structure

Homogeneous System Interop Testing

3.2 Homogeneous system interoperability includes flight plan creation, FDMP updating plan, and forced handover takeover. Case in Figure 7, a plan from Shanghai (ZSSS) to Guangzhou (ZGGG) is created in the PDER system, while the FO is released to other systems. The FDMP of the FO is PDER. The FDC is SHER. Because the route does not pass through Hefei, the HFER is FDU not displayed in the flight plan window.

3.3 After PDER modifies the RFL, the FO is updated and republished to other systems. When the plan is handed over from PDER to the SHER sector and accepted, the plan ends in the PDER system and continues to fly in the SHER system and SHER becomes the current FDMP. When the flight is forced to hand over to the unrelated system Hefei, HFER changes from FDU to FDC. When Hefei takes over the flight, its role changes to FDMP.

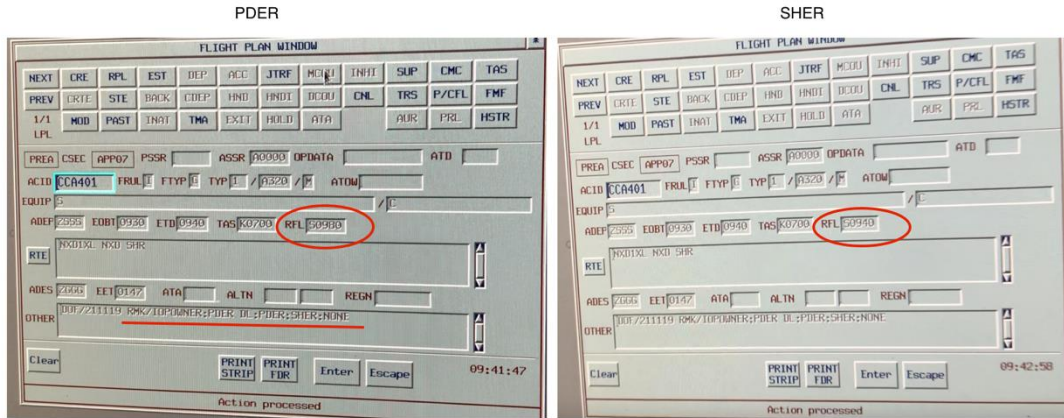


Fig.7 Test in Homogeneous System

Heterogeneous System Interop Testing

3.4 The heterogeneous system’s interoperability includes creating a flight plan, FDMP modifying the landing airport and route, and handover takeover. As in Figure 8, a plan from Guangzhou (ZGGG) to Shanghai (ZSSS) is created in the SHER system. PDER is FDC.

3.5 When the landing airport is modified to Hefei (ZSOF) and the corresponding route is modified, PDER becomes an irrelevant system and no longer plays the role of FDC. HFER becomes FDC and the plan is created in the system.

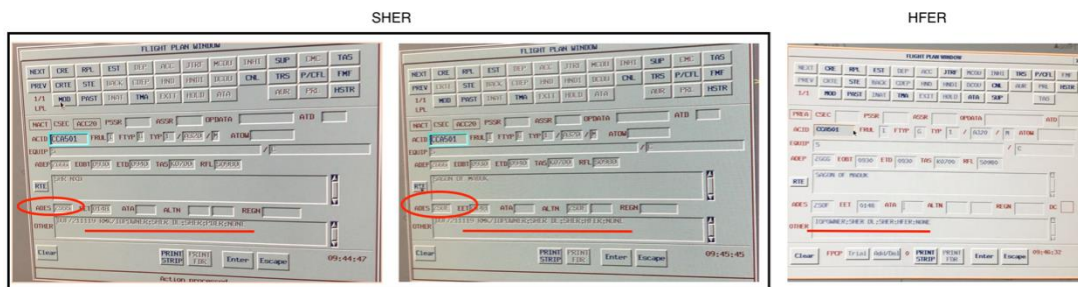


Fig.8 Test in Heterogeneous System

Degraded Mode Interop Testing

- 3.6 The studies and tests are done in a homogeneous system with two cases.
- In the first case, the SHER, which was originally an FDMP, is degraded. At this time, the SHER becomes an autonomous operation mode. The PDER that the route passes through next becomes the new FDMP and takes over the flight forcibly. When SHER reconnects, FDMP is still PDER since PDER has already taken over the flight.
 - In the second case, the PDER, which was originally an FDC, is degraded. At this time, the PDER is in an autonomous operation mode and is forced to take over the flight, and becomes the FDMP. SHER remains in network operation mode and maintains the FDMP unchanged. When the PDER is reconnected, the MMI will prompt the manual selection of a

new FDMP and control authority, due to the conflict between the current control authority PDER and pre-break control authority SHER of the flight.

4 CONCLUSION AND OUTLOOK

4.1 Through the above studies and tests, SWIM-based interoperability of ATMAS is theoretically feasible. Compared with the mature application of interconnection technologies such as AIDC and 4029.3, it has the following characteristics:

➤ From point-to-point communication or reporting network system to star network structure, the network structure of system interconnection is simplified.

➤ In a data publishing/subscribing mode, it provides information services for the required systems, and all relevant parties can join the network as needed, and receive, modify, distribute data, etc., which has strong scalability.

➤ Using the FIXM format as a data model has the characteristics of format versatility, rich information, and strong expansibility, and it is easier for relevant parties to accept.

➤ Compared with the message-based method, the FO publishes data immediately after modification, and the data update content is richer and more real-time.

➤ The traditional approach has many duplicated flight messages and low message utilization. IOP introduces the concept of roles, and data is published only to roles/participants subscribed to the FO. At the same time, the data of FO is divided into multiple data clusters, and only the modified data clusters are published each time. Therefore, it has the characteristics of high data transmission efficiency.

4.2 This research is carried out on the test platform under the same local area network. It is expected that practical exploration can be carried out in the real SWIM network environment in the future. Expand more interoperability scenarios (such as WIXM, AIXM) and other perspectives for further research.

4.3 Meanwhile, the research confirms that the implementation of FO and IOP concepts among heterogeneous systems requires extensive application level modifications (ATMAS, especially FDP). Look forward to the further improvement of FO/IOP and other related standards represented by ED-133, which will lay the foundation for the industrialization and promotion of SWIM-based flight data exchange in the ATMAS.

5 ACTION BY THE MEETING

5.1 The meeting is invited to:

- a) note the information contained in this paper; and
- b) discuss any relevant matter as appropriate
