９．SWIM 構築技術の分析と実証実験

監視通信領域　※呂　暁東，古賀　禎，塩見　格一，住谷　泰人

1. Introduction

The expected increase in aviation capacity demands, economic pressure and attention to the environmental impact are relying ever more on accurate and timely information. Such information must be organized and provided through flexible means that support system-wide interoperability, secured seamless information access and exchange. This system will result in a more cost and time efficient exchange of information between providers and users.

However, today's Air Traffic Management (ATM) system comprises a wide variety of applications developed over time for specific purposes. It is characterized by many custom communication protocols, and each of them has its own self-contained information system. Each of these interfaces is custom designed, developed, managed, and maintained individually and locally at a significant cost. Moreover the ways that ATM information is defined, provided and used are specific for most of the ATM systems. Therefore, this point-to-point communication is difficult to upgrade with new technologies, information exchange is not globally harmonized, and information security is poor [1].

The System Wide Information Management (SWIM) concept is to complement human-to-human communication with machine-to-machine (M2M) communication, and improve data distribution and accessibility in terms of quality of the data exchanged. Therefore, implementation of the SWIM concept must address the challenge of creating an interoperability environment which allows the SWIM IT systems to cope with the full complexity of operational information exchanges [1][2].

The global improvements in information management are intended to integrate the ATM network in the information sense, not just in the system sense. The SWIM concept provide not only system architecture for the delivery of information services to support meeting the expectations of the ATM community in different key performance areas, but also a common understanding of the different domains of information. Some exchange modes have been developed for some information domains, such as the aeronautical information exchange model (AIXM), the flight information exchange model (FIXM) and the weather information exchange model (WXXM) [2].

The International Civil Aviation Organization (ICAO) has made efforts to promote the SWIM concept and establish the communication and information standards. Over the course of the past years, research into SWIM concepts and solutions has taken place, and are already under various stages of development in different countries. Modernization programs such as Next Generation Air Transportation System (NextGen) in the United States and Single European Sky ATM Research (SESAR) in Europe both consider the implementation of SWIM as a fundamental requirement for future ATM systems. The system architectures and development methodologies of these two systems are analyzed in this paper.

The main objectives of SWIM is not only to achieve seamless integration among geographically distributed and heterogeneous systems in the air transportation field but also to enable seamless information sharing among the multiplicity of stakeholders in the ATM domain. Moreover, these objectives should be achieved not only in the local area but also in the global scale. To promote the development of SWIM system, the project of Mini Global Demonstration (MGD) has been conducted by the Federal Aviation Administration (FAA) to exchange air transportation information among different Air Navigation Service Providers (ANSPs) by using standardized information exchange models. The results of this demonstration and the lessons learned from this experience are also introduced in this paper.

The paper is structured as follows. In the next section, the SWIM framework and governance are described. In section 3, research and development of SWIM in Europe and USA are analyzed. The results and lessons learned of MGD are shown and discussed in section 4, and the paper is concluded in section 5.

2. SWIM

2.1 SWIM Framework

The SWIM definition given in the ICAO SWIM Concept document is: SWIM consists of standards, infrastructure and governance enabling the management of ATM related information and its exchange between qualified parties via interoperable services.

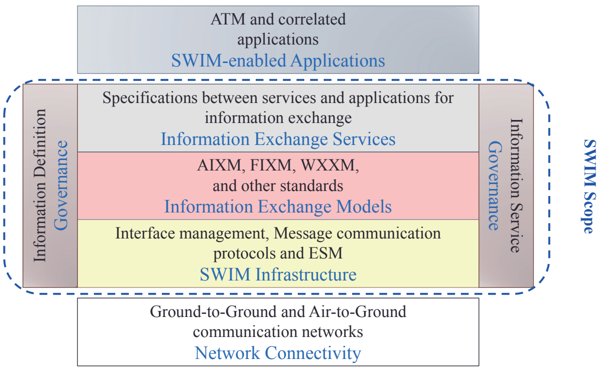

Figure 1: SWIM Framework

The SWIM Framework is shown in Figure 1. SWIM includes the information exchange standards and the infrastructure required to exchange information between SWIM-enabled applications. SWIM-enabled applications consume or provide SWIM information services using SWIM standards.

The functions of each layer are as follows:

- Network Connectivity provides consolidated telecommunications services, including ground-to-ground communication and air-to-ground communication. This infrastructure is a collection of the interconnected network infrastructures of the different stakeholders. These will be private/public Internet Protocol (IP) networks.
- SWIM Infrastructure provides the infrastructure for sharing information. It provides the core services such as interface management, request-reply and publish-subscribe messaging, service security, and enterprise service management.
- Information Exchange Models use subject-specific standards for sharing information for the above Information Exchange Services. The information exchange models define the syntax and semantics of the data exchanged by applications.
- Information Exchange Services are defined for each ATM Information Domain and for cross domain purposes where opportune, following governance specifications, and agreed upon by SWIM stakeholders. SWIM-enabled applications will use information exchange services for interaction.
- SWIM-enabled Applications of information providers and information consumers around the globe publish and/or use information. Individuals and organizations, such as air traffic managers and airspace users, will interact through applications inter-operating through SWIM.

2.2 SWIM Governance

In a loosely coupled environment such as SWIM where services are provided and consumed by a number of entities, governance is essential. Governance establishes the processes to assure that appropriate rules, policies, and standards are followed.

Governance defines the chains of responsibility, authority, and communication, as well as the measurement and control mechanisms to enable participants to carry out their roles and responsibilities.

Moreover, to achieve the service assurance, governance of information definition and information service is necessary. SWIM requires governance for the collaborative specification and definition of information within existing domains, across domains and within potential new domains. And the flexibility is also required to take into account the local and regional differences due to specific operational requirements.

Another important aspect of SWIM is the overall governance of the service approach. A key component of the SWIM Concept is the service lifecycle, from the initial identification of the business need for a possible information service through the following stages - proposal, definition, development, verification, deployment, deprecation and decommissioning. During the life of an information service, one also should expect that an information service will need to be changed for various reasons and updates will be necessary. Managing the change of an information service once it is in widespread use is much more challenging than creating the initial service; this is because of the countervailing pressures of stability versus improvement.

3. Comparison

A key element of both SESAR and NextGen is SWIM, which is a focus on how the technologies and systems will enable shared awareness for more efficient use of airspace and better air safety. However, because of different situations and industry structures, the implementation frameworks for each are radically different.

3.1 System Architecture

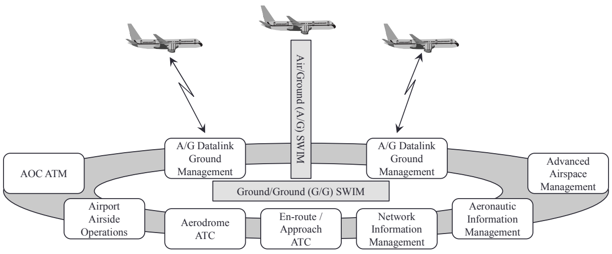

Figure 2: System of SESAR

As Europe comprises several member states that each has its own ATM system, the Web based decentralized architecture is adopted to support flexible and modular sharing of information and provide transparent access to ATM services. As shown in Figure 2, SESAR SWIM is supported by a set of architectural elements allowing exchange of data and information service across the entire European ATM system. In addition, it integrates Ground-to-Ground and Air-to-Ground data and ATM services exchange [3][4][5].

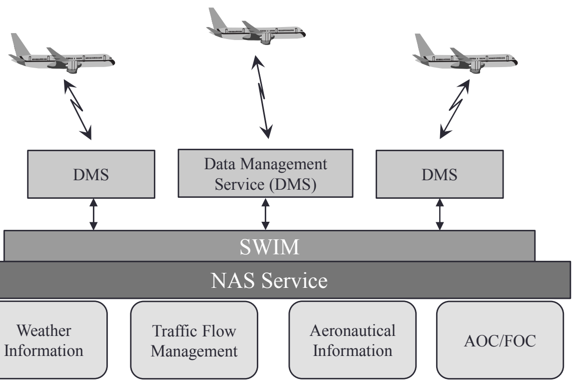

Figure 3: System of NextGen

For US requires close internal coordination between various government-run systems to ensure interoperability of services delivered by a variety of consortium, the centralized information provision architecture that is constructed on the enterprise infrastructure is utilized. As shown in Figure 3, NextGen SWIM envisions a virtual network in which each node represents a part of the system to provide a set of data and information services. The users access the system and automated tools are used to ensure adequate data provision and Quality of Service (QoS). And with the aircraft serving as a node on the network, it also encompasses the ability of Aircraft Access to SWIM (AAtS) [6][7].

3.2 Information Model

The description of data, information and service in SESAR and NextGen is also different. With a more decentralized model, SESAR constructs a Reference Model for data and for data normalization and standardization (AIRM: ATM Information Reference Model). SESAR describes the information elements in terms of data models associated with different domains (flight, weather, surveillance, etc.) and describes a reference model architecture that, when used, makes the data and information available for use by the system participants [8].

NextGen, envisioning a more centralized government-run approach, describes not only data but the provision of information services in a service-oriented and networked environment. NextGen describes information elements in the terminology of “services” - using a service-oriented architecture context to describe the automated and ubiquitous nature of the key information elements serving the overall system.

The comparison of SWIM development of NextGen and SESAR is shown in Table 1.

Table 1. Comparison

	NextGen	SESAR
Network Infrastructure	FAA Telecommunication Infrastructure (FTI)	Pan European Network System (PENS)
Messaging Infrastructure	NAS Enterprise Messaging Service (NEMS)	Network Management B2B Web Services
Information Model	AIXM, WXXM, FIXM	AIRM
Approach	Top-down Centralized	Bottom-up Decentralized
Governance	FAA	EUROCONTROL

4. MINI GLOBAL DEMONSTRATION

The MGD is a project of FAA to collaborate with other ANSPs to exchange Aeronautical, Flight and Weather data by using SWIM concept and standardized information exchange models. As a member state, the team of Japan Civil Aviation Bureau (JCAB) in which the technical support is Electronic Navigation Research Institute (ENRI) participated to this demonstration. In this demonstration, not only the semi-live data in FIXM of practical operation system is shared among the member states, but also the simulation based scenarios with standardized message exchange between different partners are demonstrated.

4.1 System Structure

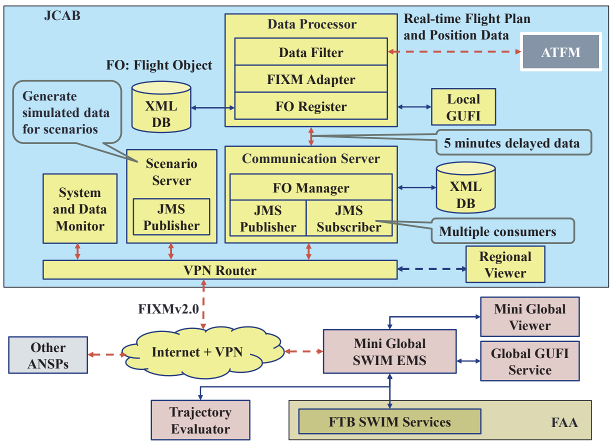

Figure 4: System Structure of Demonstration

In the MGD, all member states used the Virtual Private Network (VPN) over Internet connecting their own demonstration systems to the Mini Global SWIM EMS (Enterprise Messaging Service). Then, all member states shared the information by applying standardized message format. The demonstration system of Japan is composed of two main subsystems, Data Processor and Communication Server, as shown in Figure 4. The system not only provides a unique flight ID to each departure flight by using a local Globally Unique Flight Identifier (GUFI) service, but also manages the flight objects of all departure, arrival and pass flights based on the GUFI.

The ATFM is an Air Traffic Flow Management system for practical operation. The real-time flight plan and track data are forwarded to the Data Processor. The Data Filter extracts the required data, and then the FIXM adapter changes these data from local format into FIXM 2.0 format. The Flight Object (FO) Register gets a unique identifier for each flight from the Local GUFI service, and put the flight data into the Extensible Markup Language (XML) Database (DB).

For information exchange, both Java Messaging Service (JMS) based Publish/Subscribe and Web Service based Request/Reply communication methods are applied. The JMS based Publish/Subscribe communication is the main method for FIXM information exchange. The communication server responses for message exchange between the local system and the Mini Global EMS via the established VPN connection. The 5 minutes delayed data was utilized in the demonstration. The FO manager has two functions. One is to get the flight data from the XML DB and generate the FIXM messages and publish them to the MG EMS. The other is to receive the subscribed flight data from the MG EMS and save them into the XML DB.

Because of the network delay, the multiple consumers of JMS subscribe are utilized for improving the rate to get the messages from the JMS queue server. The Scenario Server has the functions to achieve all designed use cases by generating the simulated data for each scenario. The System and Data Monitor is to monitor the system status and check data validation.

4.2 Demonstration Results

In the MGD, not only the semi-live data for the international departure flights from the main airports of Japan was published, but also more than one simulated data based scenarios were implemented. In the demonstration, only US, Australia and Japan provided the semi-live data as shown in Figure 5. By using Mini Global Viewer, the detail information of each flight and the content of each message can be shown and exported.

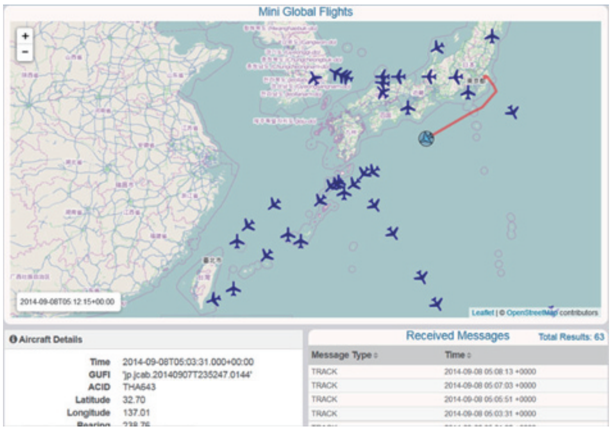

Figure 5: Semi-live Flight Data

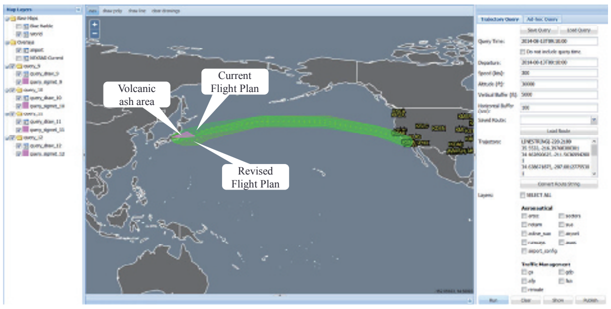

Figure 6: Simulation based Scenario

By utilizing FIXM, AIXM, and WXXM, several scenarios were developed and each of them demonstrated the sharing information on borderless. In Figure 6, the scenario of volcanic ash for the flight from Tokyo to Los Angeles is shown. The main purposes of this scenario are to check the basic functions of SWIM based communication, and to confirm the message exchange by FIXM, AIXM and WXXM. At first, Significant Meteorological Information (SIGMET) of volcanic ash was published by JCAB in WXXM format. Then, the current Flight Plan was evaluated by using this weather information and revised Flight Plan was published by JCAB. Next, the departure, boundary coordination and track messages were published and shared between JCAB and FAA. Finally, the arrival message and surface status were published by FAA.

4.3 Lessons Learned

Although the approach of definition for flight data in FIXM 2.0 is versatility and flexible, it is a little difficult to be utilized in the real systems in which many constraints and limitations are set for practical applications. And there is no model for data mapping from current flight data to FIXM data, which will make problems in the data translation. Moreover, because the information exchange is based on the message exchange, how to use these data to define the different message types is also not clear.

The JMS is an effective communication method in the enterprise network. From this demonstration, we can see that the network delay affects the performance of subscribing messages from JMS queue server. Although increasing the number of consumers can improve the performance, it is not a good method to solve the problem. Maybe the Cloud based EMS can solve this problem, or other technologies should be utilized to improve the performance.

In this demonstration, all stakeholders used the MG EMS to exchange the information. If ANSPs use different technologies, for example, Web based approach, how to share the information by using Global EMS should be considered. Moreover, the progress of development of SWIM system in different countries is different. How to assure the consistence of GUFI in the old and new systems coexisting environment should also be taken into account.

5. Conclusions

In this paper, the SWIM concept and framework are described. Moreover, the approaches of SWIM development in Europe and USA are introduced and analyzed. Finally, as a main member state, JCAB technically supported by ENRI participated to the project of MGD to exchange Aeronautical, Flight and Weather data with other ANSPs by using SWIM infrastructure and standardized information exchange models. To assure the timely information exchange both locally and globally, the appropriate system architecture, network and communication technologies are required.

In addition, because of the different requirement and environment, it is difficult to assure the seamless information exchange between the SWIM systems in different nations or regions. To improve the global interoperability, Mini Global II has been launched. In this demonstration, the local SWIM providers will be integrated into the Global EMS (GEMS) messaging exchange infrastructure. The GEMS infrastructure will enable demonstration of future applications to benefit Global ATM.

REFERENCES

[1] Global Air Traffic Management (ATM) Operational Concept, ICAO Doc. 9854, 1st ed., ICAO, 2005.

[2] System Wide Information Management (SWIM) Concept, 1st ed., ICAO, 2014.

[3] "SESAR SWIM web site," in http://www.sesarju.eu/programme/workpackages/swim/.

[4] SESAR SWIM Concept of Operations, edition 00.02.03, SESAR Joint Undertaking, June 2012.

[5] European Air Traffic Management Master Plan, 1st ed., SESAR Joint Undertaking, 2009.

[6] "FAA SWIM web site," in https://www.faa.gov/about/office_org/headquarters_offices/ato/service_units/techops/atc_comms_services/swim/.

[7] Operational Concept for the Next Generation Air Transportation System (NextGen), 2nd ed., Joint Planning and Development Office, 2008.

[8] D. D. Crescenzo, A. Strano, and G. Trausmuth, "System wide information management: The swim-suit prototype," in Proc. of Integrated Communications Navigation and Surveillance (ICNS) Conference. IEEE, April 2010.