１３．FF-ICE 検証実験の報告と分析

監視通信領域　※呂　暁東，古賀　禎，住谷　泰人

1. INTRODUCTION

The Flight and Flow Information for a Collaborative Environment (FF-ICE) is a System Wide Information Management (SWIM) concept-oriented operation [1][2]. Its concept has been developed by International Civil Aviation Organization (ICAO) to illustrate information for flow management, flight planning, and trajectory management associated with Air Traffic Management (ATM) operational components. It will be used by the ATM community as the basis for which ICAO Standards and Recommended Practices (SARPs) will be developed in order to ensure that the FF-ICE concept can be implemented globally [3].

FF-ICE implementation has been divided into two phases proposed by the ATM Requirements and Performance Panel (ATMRPP). The first phase is FF-ICE Planning (FF-ICE/1) that is focused on achieving the interoperability of ground-to-ground information exchanges by using standard information exchange models in the pre-departure phase of flight. The second phase is FF-ICE Execution (FF-ICE/2) that will support Trajectory Based Operation (TBO) through ground-to-ground and air-to-ground (A/G) SWIM exchanges in the post-departure phase of flight. These information exchanges will enable a common operational picture between aviation stakeholders in order to support collaborative ATM and TBO. Therefore, ATM Service Providers (ASPs), Airspace Users (AUs), and other aviation stakeholders will need to determine the operational processes, procedures, and automation changes required for FF-ICE implementation [4].

However, with the different conditions, it is difficult for all ASPs to transform from the current operation to the FF-ICE/1 based operation at the same time. Moreover, not all AUs will adopt the changes at the same time. Therefore, the impact of FF-ICE changes for ASPs, particularly relative to adjacent Flight Information Regions (FIRs) and AUs, is unknown and unpredicted at this time.

To validate the ICAO provision changes for potential implementation, accounting for operational and technical interactions between different ATM systems within Air Navigation Service Providers (ANSP) and AU domains, the International Interoperability Harmonization and Validation (IIH&V) project has been conducted by Federal Aviation Administration (FAA). Three Validation Exercises consisting of Tabletop and Lab exercises are planned in the 2016-2018 timeframe to provide recommendations to enhance implementation guidance material. The results and observations of this project and Tabletop exercises have been reported by FAA at ATMRPP meetings [5][6][7][8].

In order to promote the SWIM construction and the FF-ICE implementation in the Asia-Pacific region, Japan Civil Aviation Bureau (JCAB) joined this project from January, 2017. As a technical supporter of JCAB, Electronic Navigation Research Institute (ENRI) developed a test system for validation and participated Lab exercises of Validation 1 and Validation 2/3 in collaboration with FAA, NAV CANADA, NEC, NTT Data, ANA and JAL. In this paper, the development and analysis of Lab exercises related to the regional SWIM implementation are reported. Moreover, the problems and challenges for constructing the FF-ICE operating environment to include interactions of the ATM stakeholders using data, systems, and services through a SWIM environment are discussed.

The paper is structured as follows. In the next section, the FF-ICE concept and the overview of IIH&V are introduced. In section 3, the development of local system for Validation 1 and Validation 2/3 Lab exercises and the lessons learned are presented and analyzed. The problems and challenges to achieve interoperability is discussed in section 4, and the paper is concluded in section 5.

2. FF-ICE CONCEPT AND IIH&V

2.1 FF-ICE Concept

The present-day ICAO flight planning provisions were developed on the basis of a manual, paper-based, point-to-point, teletype communications system. A fundamental change is required to support the implementation of the Global ATM Operational Concept that has greater data requirements [9]. These include system-wide information sharing, providing early intent data, management by trajectory, coordinated decision making, and high automation support requiring machine readability and unambiguous information [10]. The limitations of current flight planning provisions and how the FF-ICE concept addresses them are summarized in Table 1.

Table 1. Current Provisions and FF-ICE Concept

Items	Current Provisions	FF-ICE Concept
Information sharing	Multiple two-party exchange	All related stakeholders
Advance Notification	Short term	Long term
Flight Information	Local management	GUFI based global management
Information distribution	Peer-to-peer communications	SWIM based interoperability
Information security	Single policy	Multi-layered governance
Information set	Local definitions; Fixed data lengths	Standard models; Flexible format
Derivable information	Independence; Inconsistency	Interaction; Consistency

In order to achieve a safe, secure, efficient and environmentally sustainable air navigation system at global, regional and local levels, future ATM requires a collaborative environment with extensive information content. The FF-ICE concept will provide a globally harmonized process for planning and providing consistent flight information [1].

FF-ICE/1 is the first step towards achieving the FF-ICE concept, and is primarily concerned with pre-departure data and processes in a mixed-mode environment. This will involve the interoperability for flight plan coordination between partners that have SWIM flight plan filing capabilities and partners that are filing through existing systems.

2.2 Overview of IIH&V

As a main technical supporter of JCAB, ENRI is collaborating with FAA and other international aviation participants on the IIH&V to validate FF-ICE concepts for potential implementation in the local system, as well as the interoperability between the local system and international ANSPs components. It is expected that this project will align current and future Collaborative Action for Renovation of Air Traffic Systems (CARATS) activities with the ICAO provisions to improve the accuracy and availability of flight information, and consistency of flight planning in different ATM environments and ANSP domains. This project consists of three Validation Exercises consisting of several Tabletop and Lab exercises to validate key ICAO provisions [11].

The goal of Validation 1 is to evaluate the viability of the implementation of FF-ICE/1 in the 2020 timeframe. That includes Flight Plan Submission, Monitoring, and Distribution which targets the pre-departure coordination of flight plans between ASPs in a mixed-mode environment. Validation 2 and 3 expanded trajectory negotiations to the post-departure portion concerning with the A/G SWIM integration by applying Electronic Flight Bag (EFB) with single or bi-directional data link communications [12].

The Tabletop Exercises focus on operational, policy, and procedure questions. The development of the system capability in Lab Exercises is determined according to these discussions. Tabletop Exercises are performed for all vignettes. Based on defined down selection criteria, some scenarios of Tabletop Exercises are selected and conducted as Lab Exercises. Results from these validation exercises will be used to inform the development of any future implementation guidance, ASP procedures, AU procedures, and future revisions of ICAO Provisions (Figure 1). In the next section, additional details on Lab Exercises of Validation 1 and 2/3 are presented.

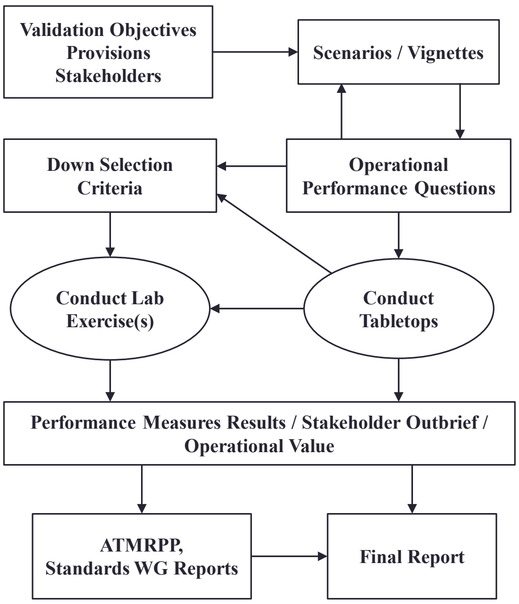

Figure 1: Validation Exercise Approach

3. Lab Exercises

3.1 Validation 1 Lab Exercise

(1) System Architecture

In the Lab exercise of Validation 1, there are two Global Enterprise Messaging Service (GEMS) providers that facilitate data sharing between a variety of partners and applications. The mixed-mode environment that includes participation by both FF-ICE/1 capable and FF-ICE/1 non-capable ASPs is considered. The FF-ICE/1 capable ASP and AU are referred to as eASP and eAU (enabled ASP and AU). As shown in Figure 2, the FAA, NAV CANADA and legacy ASPs connect to SkyFusion Frontier (SFF), which is supported by Harris Corporation. NEC provides the GEMS connections (SBN) to local eASPs and eAUs (JCAB, JAL, ANA).

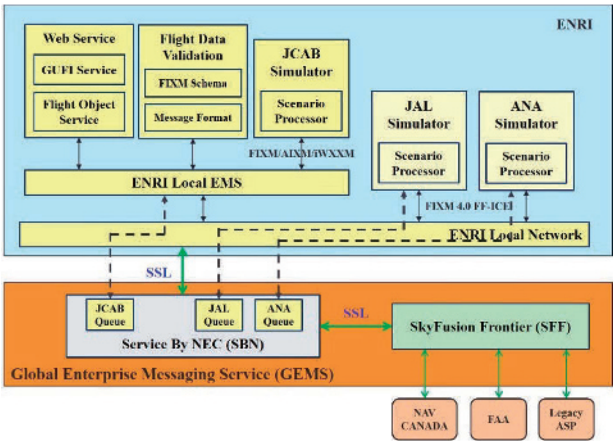

Figure 2: System Architecture for Validation 1

The GEMS Providers are charged to enforce the use of the standardized aeronautical, flight and weather exchange models (AIXM, FIXM and iWXXM) with the updated versions for each of their SWIM nodes to ensure the interoperability of the exchanged information [13]. The communication between SFF and NEC is based on Secure Sockets Layer (SSL). And the SSL is also used for communication between NEC and regional users. The communication standard for Publish/Subscribe messaging is Advanced Messaging Queuing Protocol (AMQP).

(2) Validation

According to the definition in the ICAO FF-ICE/1 Provisions, the following message types in the FIXM 4.0 format are validated for the pre-departure phase of flight. There are two phases in the FF-ICE/1, Preliminary phase and Filed phase. In each phase, eASPs should reply to the eAU regarding operational acceptability of their flight plans.

The validation of flight information exchange model (FIXM 4.0) implementation is an essential component of the Validation 1 Lab exercise. The goal of the Lab exercise is not only to validate FF-ICE/1 messages but also evaluate all states and status options of the messages. The FF-ICE/1 messages based operations of JAL in coordination with FAA, NAV CANADA and JCAB for the KJFK-RJAA scenario are shown in Figure 3.

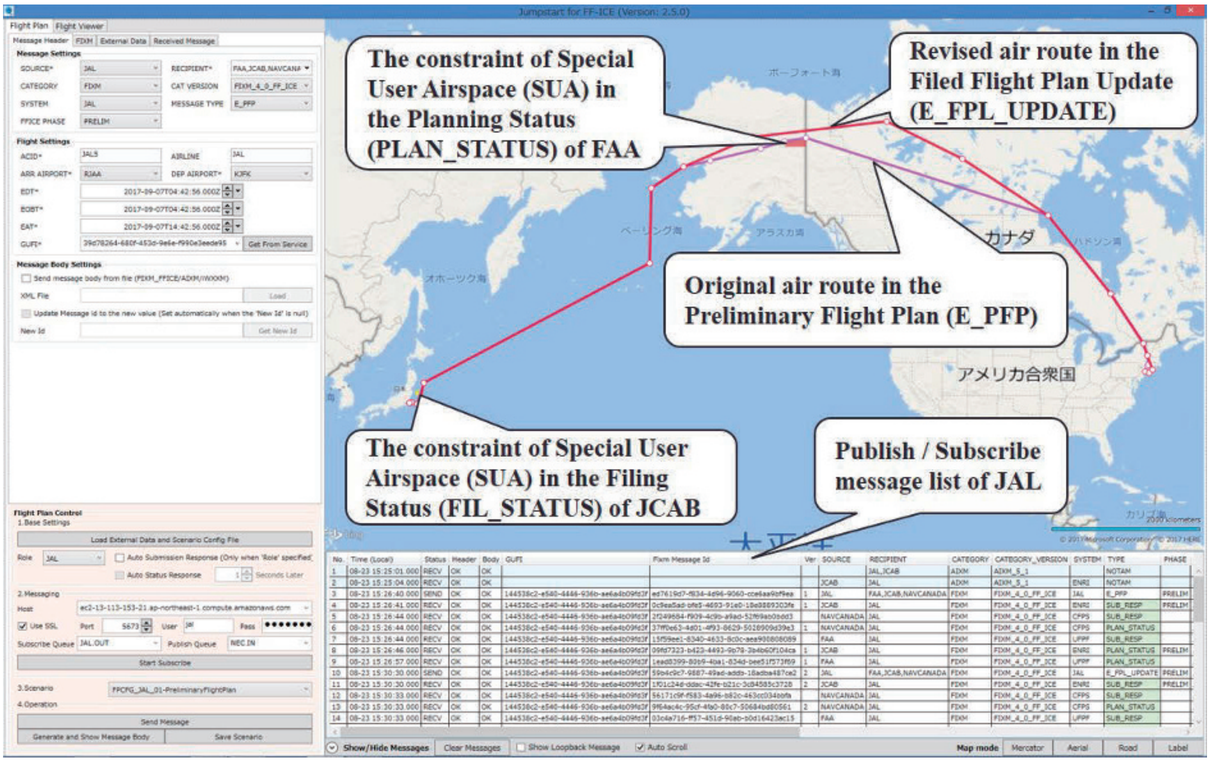

Figure 3: JAL Simulator

Table 2. Message Types

Message Types	Descriptions
E_PFP	Preliminary Flight Plan
E_FPL	Filed Flight Plan
SUB_RESP	Submission Response
FIL_STATUS	Filing Status
PLAN_STATUS	Planning Status
E_FPL_UPDATE	Flight Plan Update
E_ARRIVAL	Arrival
E_DEPARTURE	Departure
E_CANCEL	Cancel
E_TRIAL_REQ	Trial Request
E_TRIAL_RESP	Trial Response
E_INFO_REQ	Request Flight Information
E_INFO_RESP	Flight Information Response

3.2. Validation 2/3 Lab Exercise

(1) System Architecture

As shown in Figure 4, the main differences between the test system of Validation 2/3 and Validation 1 include the addition of the Data Management Service (DMS) and the EFB simulator. And to increase efficiency by removing extra process for information exchanges, all SWIM-enabled applications are connected to the ENRI Local EMS that is directly connected to the SBN.

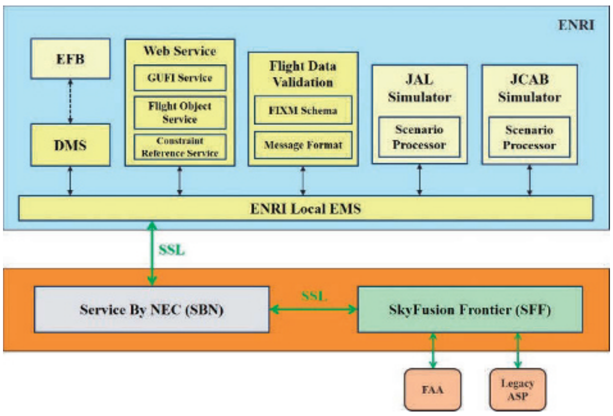

Figure 4: System Architecture for Validation 2/3

The DMS is an access point for achieving Aircraft Access to SWIM (AAtS) developed to store, manage, filter, and deliver ground data and air data to related users. The EFB simulator was developed to subscribe

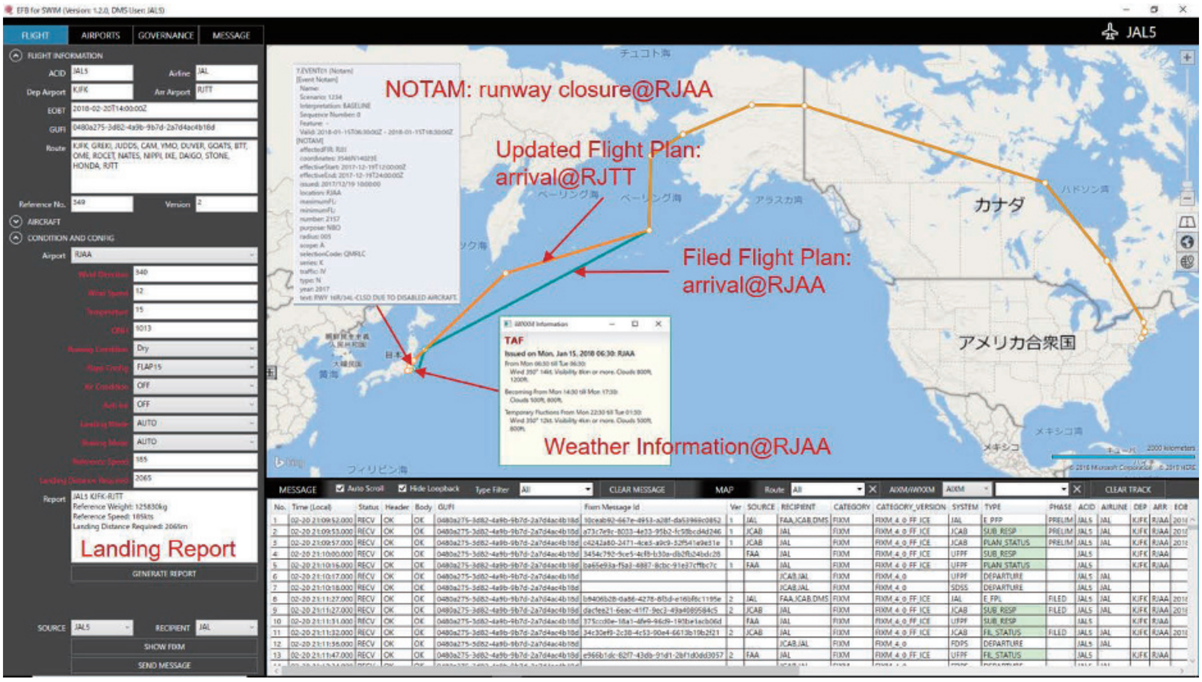

Figure 5: EFB Simulator for Validation 2/3

related FIXM, AIXM and iWXXM messages for a certain aircraft; show related information and documents on the map; generate landing report according to the on-board and ground information and submit it to the DMS; request NOTAM, METAR and TAF information from the ground SWIM services.

(2) Validation

To continue with the scenario proposed in Validation 1, the JAL5 from KJFK to RJAA uses EFB simulator for post-departure negotiation to achieve A/G SWIM integration. Before entering the FUKUOKA FIR, a digital NOTAM was received on the EFB that the primary runway at the RJAA has been closed due to a disabled aircraft.

As shown in Figure 5, according to the latest weather information for RJAA received via A/G SWIM and the on-board data of aircraft, the EFB generated a landing report and identified that diverting to RJTT is necessary due to a runway closure at RJAA. Using Trial Request and Update Request messages while enroute, the JAL5 was able to negotiate the diversion with related stakeholders.

In this scenario, the two new messages, Update Request and Enroute Status are added for FF-ICE execution phase to make distinction between pre-departure and post-departure change requests. Unlike the pre-departure Flight Plans and Flight Plan Updates, the Update Request does not include the flight plan version. A flight plan version is not included post-departure because the controller must take action, and could also initiate a modification without a request from the AU, and therefore versioning number would get out of order.

3.3. Analysis

In the FF-ICE/1 messages, there are two parts. One is message information part that includes contact information, flight plan version, and referenced constraints. The other is flight information part, such as aircraft information, 4D trajectory, and GUFI.

A key enabler to sharing flight data internationally is having the ability to unambiguously identify each flight. This is accomplished by having a GUFI assigned to each unique flight. A unique flight is defined as a single operation of an aircraft from takeoff to touchdown. The GUFI is intended to provide a unique reference to a specific flight. Its purpose is to assist in associating a message to the correct flight and to help in distinguishing between similar flights.

However, in the draft of FF-ICE/1 Implementation Guidance, it does not specify GUFI in Submission Response as a mandatory or optional field. Including the GUFI allows participants to easily identify Submission Responses as part of their respective FF-ICE/1 message conversations (as opposed to relying solely on the reference message ID), and allows developers to be consistent in their implementations. It is therefore recommended that, at least during initial implementation, the GUFI should be included in all FF-ICE/1 messages.

For consistent and automatic message process in a certain operation, each message should have different message identifiers. A message identifier allows identification of a message exchange between two parties. And a message identifier between two parties should be unique for a certain operation or a certain time period.

In addition, to assure all stakeholders are using the same flight plan information, the eAU is required to provide an indication of the flight plan version. The flight plan version should be incremented by the eAU each time a Flight Plan Update is submitted i.e. at least one flight plan data element is changed. The flight plan version number is intended to provide both a reference to a particular version but also an indication of the sequence in which versions have been created. The last flight plan version provided by the eAU to an eASP is expected to be included by the eASP when providing feedback in the form of a Submission Response or a Planning or Filing Status.

However, in the FIXM v4.0, the Flight Plan Version field is a free text field without any mask. This can lead to incompatible data in this field. It is recommended that this field should be defined as an INTEGER and more details for processing the incorrect flight plan version number should be given in the implementation guidance.

In the Lab exercise, there is an assumption that each eASP is able to provide constraints, such as aeronautical information, traffic flow management data, and severe weather conditions to the eAU. The eASP evaluation and continuous monitoring of Preliminary and Filed Flight Plans will check for and send message updates for changes to published constraints affecting the route. It not only assists the eAU in determining the optimal route/trajectory for a flight by identifying the operational environment and ATM constraints applicable to the flight as proposed, but also enables eASPs to obtain an earlier, more detailed and more accurate assessment of the anticipated traffic demand.

However, how to decide the relevant ASPs for a certain operation is not clearly defined in the related documents. In the FF-ICE/1 Implementation Guidance, a relevant ASP is defined as any ASP who could potentially issue constraints on a flight. And the FF-ICE/1 Provisions states a relevant ASP is any ATM Service Provider whose airspace is along the flight plan route of flight or along the possible route of flight described in filed routing to a revised destination. The different interpretations exist within different participants to determine relevant ASPs who should receive the flight plan from the originator. Further examples would be helpful to clarify off-nominal cases and avoid different interpretations of the FF-ICE/1 Implementation Guidance.

4. DISCUSSION

4.1 Interoperability

From the view of technical aspects, to achieve the interoperability of SWIM services, the technical interoperability, the semantic interoperability and the process interoperability are required.

The technical interoperability is the basis of SWIM concept-oriented operation. Based on acceptable technology standards, the common and secure infrastructure for network communication and message exchange should be constructed at local, regional and global levels.

The implementation of semantic interoperability requires the defined and precise meaning of exchanged information that can be preserved and understood by all related stakeholders. And it need to bundle of information into meaningful messages based on the different information exchange models that have been defined by ICAO. As a result, it enables new interoperable services to be identified, designed and implemented based on the different information exchange services.

To assure the consistent operation, the process interoperability is necessary to perform actual information exchange based on appropriate process alignment. Coordinated and standardized processes enable SWIM responsible authorities as well as stakeholders to work together based on sufficiently aligned processes. Therefore, the metadata, format and process of different messages should be defined in advance to ensure that eAUs and eASPs implement the global operation.

4.2 Challenges

The SWIM-based FF-ICE operation will provide related information in greater detail and allow the eAU and the eASP to share their expectations in an unambiguous manner via the exchange of trajectory information. However, as shown in Table 3, there are still many problems and challenges we should face to achieve the FF-ICE oriented operation in local, regional and global areas.

For standards-based interoperability, the routing standards between different systems to ensure message delivery should be addressed. And for A/G SWIM integration, the coordination method between different DMSs located in different places should be considered. For seamless information sharing, additional guidance is needed on translating between ATS and FF-ICE messages to avoid ambiguity and data loss. It was observed that not all elements map one-to-one between ATS and FF-ICE messages and this can result in misinterpretation between translators and message consumers. And the data and information to improve A/G SWIM integration should be defined in the current standard information exchange models. For

Table 3. Problems and Challenges

SWIM	FF-ICE	Problems and Challenges
Infrastructure	Standards-based Interoperability	Messaging infrastructure for FF-ICE operation
Exchange Models	Seamless information sharing	FIXM-based definition for FF-ICE messages
Exchange Services	Situation-awareness service cooperation	Heterogeneous services provision and utilization
Governance	Life-cycle management	Definition for quality, security and business rules

situation-awareness service cooperation, it is required to establish a common format for referencing constraints in AIXM and iWXXM over the different systems.

Moreover, to facilitate interoperability and harmonization and avoid integration issues, it was necessary for participants to share a common, agreed-upon set of business/data rules which were derived from the FF-ICE/1 Provisions and Implementation Guidance. Participants could validate messages using methods compatible with their needs and resources, as long as the validation method used the common set of business rules. This helped avoid issues where participants may have interpreted the FF-ICE/1 Implementation Guidance and related documents in different ways.

5. Conclusions

In this paper, the overview of IIH&V international project for validating FF-ICE oriented operation is introduced. And the development and analysis of Lab exercises of Validation 1 and 2/3 related to the regional implementation is reported. In addition, according to a certain scenario, the operational processes, procedures, and automation changes required for FF-ICE provision implementation between ASPs, AUs, and aviation stakeholders are clarified. Finally, the problems and challenges for constructing the FF-ICE operating environment to achieve interoperability are discussed.

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