[EN-A-056] Coordinated Validation for SWIM Concept-Oriented Operation to Achieve Interoperability

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Abstract: The Flight and Flow Information for a Collaborative Environment (FF-ICE) is a System Wide Information Management (SWIM) concept-oriented operation. FF-ICE Step 1 (FF-ICE/1) provisions will provide guidance for new flight planning and filing capabilities structured to improve collaboration and coordination prior to departure. This information exchange will enable a common operational picture between aviation stakeholders in order to improve strategic planning. However, with the different conditions, it is difficult for all Air Traffic Management (ATM) Service Providers (ASPs) to transform from the current operation to the FF-ICE/1 based operation and not all Airspace Users (AUs) will adopt the changes at the same time. To validate the International Civil Aviation Organization (ICAO) provision changes for potential implementation of FF-ICE/1, the International Interoperability Harmonization and Validation (IIH&V) project has been conducted by FAA. As a technical supporter of Japan Civil Aviation Bureau (JCAB), ENRI participates this project. In this paper, the observations and analysis of validation exercises consisting of Tabletop exercises and Lab exercises related to the regional SWIM implementation will be reported. Moreover, the operational processes, procedures, and automation changes required for FF-ICE/1 provision implementation between ASPs, AUs, and aviation stakeholders are clarified. Finally, the problems and challenges for constructing the FF-ICE/1 operating environment to include interactions of the ATM stakeholders using data, systems, and services through a SWIM environment are discussed.

Keywords: System Wide Information Management (SWIM), Flight and Flow Information for a Collaborative Environment (FF-ICE), ATM Service Providers (ASPs), Airspace Users (AUs), interoperability, validation

1 INRODUCTION

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 Step 1 (FF-ICE/1) provisions will provide guidance for new flight planning and filing capabilities structured to improve collaboration and coordination prior to departure. The provisions allow for Airspace Users to receive feedback on a planned flight as Air Navigation Service Providers (ANSPs) can provide constraints far in advance of departure. This information exchange will enable a common operational picture between aviation stakeholders in order to improve strategic planning. 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/1 provision implementation [4].

However, with the different conditions, it is difficult for all ATM Service Providers (ASPs) to transform from the current operation to the FF-ICE/1 based operation at same time. Moreover, not all AUs will adopt the changes at the same time. Therefore, the impact of FF-ICE/1 changes for ASPs, particularly relative to adjacent Flight Information Regions (FIRs) and AUs, is unknow 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 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 current status and observations of this project have been reported by FAA at ATM Requirements and Performance Panel (ATMRPP) meetings [5][6].

In order to accelerate the FF-ICE/1 implementation and promote the SWIM concept-oriented operation in 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) participated Tabletop exercise and Lab exercise of Validation #1 that were conducted during February to August, 2017. Now, ENRI is cooperating with other members (NEC, NTT Data, ANA, JAL) to develop the evaluation system for air-ground integration validation exercises.

In this paper, the observations and analysis of validation exercises consisting of Tabletop exercises and Lab exercises related to the regional SWIM implementation is reported. Not only the potential operational feasibility challenges between ASPs and AUs, but also additional functional capabilities of communication and application required to support FF-ICE/1 are identified. Moreover, the operational processes, procedures, and automation changes required for FF-ICE/1 provision implementation between ASPs, AUs, and aviation stakeholders are clarified. Finally, the problems and challenges for constructing the FF-ICE/1 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 discussion of vignette for Tabletop 1b exercise and the observations are described. The development of local system for Validation #1 Lab exercise and the lessons learned are presented and analyzed 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 [7]. 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. The limitations of current flight planning provisions and how the FF-ICE concept addresses them are summarized in Table 1.

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.

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

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/1 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.

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 concern with the air-ground integration by applying Electronic Flight Bag (EFB).

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). Additional details on the Tabletop and Lab Exercises of Validation #1 are presented in Sections 3 and 4, respectively.

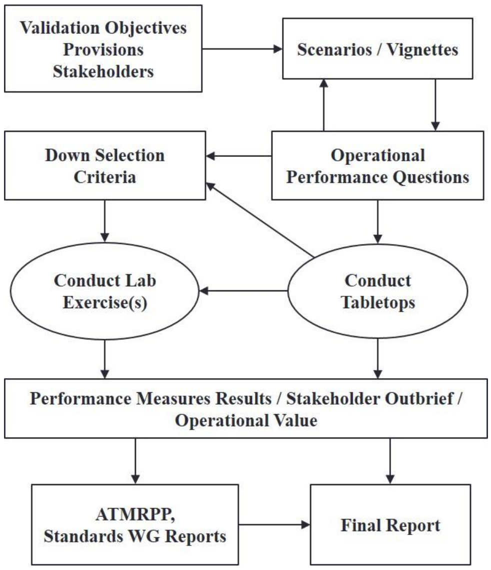

Fig. 1. Validation Exercise Approach

3 TABLETOP EXERCISE

The Tabletop Exercises are discussion-based sessions where team members meet in an informal setting to discuss their roles during an operation and their responses to particular situations. Tabletop Exercises give the user the ability to pose broad questions across numerous types of operational scenarios as well as allow for more detailed questions focused on a specific position or type of operation.

Validation #1 activities formally started with the Tabletop 1a exercise, which was held on September 27, 2016. The JCAB team jointed the IIH&V project from Tabletop 1b exercise and the objectives are as follows [8]:

1) Identify potential operational feasibility challenges with FF-ICE/1 between ASPs and AUs
2) Identify additional functional capabilities of communication and application required to support FF-ICE/1
3) Consider different implementations and FF-ICE/1 solutions across ASPs and understand how the differences affect AU operations
4) Identify the message process of FF-ICE/1 based operation and understand varying feedback and constraint definitions according to different operation levels of ASPs
5) Refine vignette and identify key topics to be validated in Lab exercise

3.1 KJFK-RJAA Vignette

To validate the operational and technical aspects of global implementation of FF-ICE/1, 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). There is no unique acronym to refer to non-capable ASP and AU.

In the Tabletop 1b exercise, several scenarios and vignettes are discussed. Each vignette is defined by the origin and destination city pairs and associated constraints. The Flight Plans are submitted by eAUs that contain additional information including 4 Dimension Trajectory (4DT), aircraft dynamics, weight, etc. This enables the eASPs to generate a more accurate model of the flight path.

The vignette proposed by JCAB is the flight planning for Japan Airlines (JAL) flight 5, a Boeing 777 aircraft with regularly scheduled service from John F. Kennedy International airport (KJFK) through the Canadian airspace to Narita International Airport (RJAA). The stakeholders of FAA, JCAB and NAV CANADA in this vignette are eASP. And the Japan Airline Air Operation Center (JAL) is an eAU. The operational views of this vignette are as follows:

1) Five hours prior to the Estimated Off Blocks Time (EOBT), the JAL publishes a Preliminary Flight Plan (PFPL) message to the all three relevant eASPs. The FAA replies to the JAL with Planning Status message that includes the Special User Airspace (SUA) constraint in Anchorage FIR.
2) The JAL publishes the PFPL Update to FAA/JCAB/NAVCANADA. The three eASPs evaluate the updated PFPL and respond with Planning Status Concur messages indicating operational acceptability of the PFPL.
3) Four hours prior to EOBT, the JAL submits a Filed Flight Plan (FFPL) message to FAA/JCAB/NAVCANADA. The JAL receives Filing Status Accept messages from all eASPs.
4) Two hours prior to EOBT, the JAL receives information from the FAA that the planned departure route has been heavily impacted with traffic during the EOBT for JAL5.

5) The JAL elects to use a Trial Request to determine whether a departure over another route would be acceptable. And Trial Response Concur message is returned from the FAA.
6) The JAL publishes a FFPL Update message for JAL5 and Filing Status Acceptance messages are received.
7) One and half hours prior to EOBT, the continuous monitoring of JCAB re-evaluates Updated FFPL and updates Filing Status message with airspace closure that is occurred in the Fukuoka FIR.
8) The JAL submits a FFPL Update message with revised air route and receives Filing Status Acceptance messages from all three eASPs.

In the Tabletop 1b, the Operational Event Trace (OET) is discussed and applied to represent the information exchanges between the operational stakeholders within the vignette. The example of PFPL submission and response by OET is shown in Figure 2.

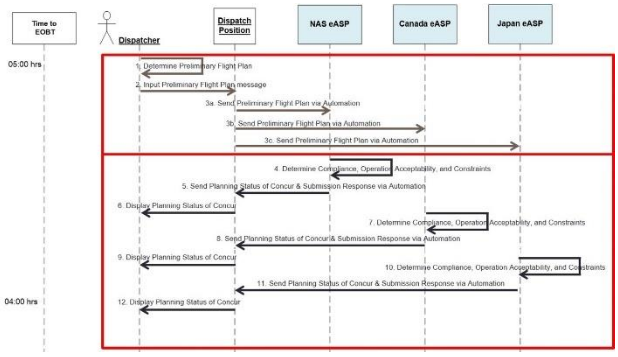

Fig. 2. Operational Event Trace

3.2 Observations

According to the Tabletop 1b exercise, some feedback to ICAO Implementation Guidance and other provisions for global aviation community have been reported by FAA [5][6]. As an Asia-Pacific regional participator, some observations for improving regional SWIM implementation are provided below:

1) To implement FF-ICE/1 based operation, not only additional operational functions for supporting FF-ICE/1 message exchange has to be developed but also the regional common communication infrastructure and service providers for network connection are necessary.
2) For national ASPs and AUs, the benefit of FF-ICE/1 based operation depends on the accuracy of four-dimensional trajectory (4DT)/flight plan and operational levels of related FIRs. The priority implementation and test operation in some density areas is more efficient for regional SWIM development.
3) For achieving efficient FF-ICE/1 based operation, the understanding and cooperation between not only the departure and arrival pair of ASPs but also adjacent and non-adjacent ASPs involved in air route are required and important.

4 LAB EXERCISE

4.1 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. As shown in Figure 3, 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 regional eASPs and eAUs (JCAB, ANA, JAL).

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 [9]. 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).

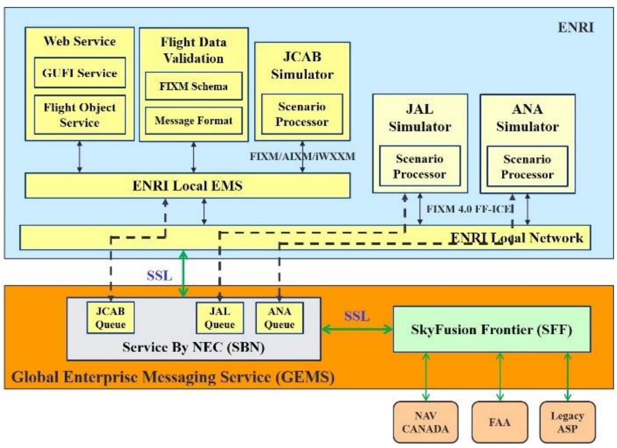

Fig. 3. System Architecture

In this Lab exercise, the evaluation systems of JCAB, ANA and JAL are constructed on the ENRI local network and EMS. There is a set of services and applications developed by ENRI that support both FF-ICE/1 based message process and local validation.

- The Globally Unique Flight Identifier (GUFI) is a key component of flight object management. The

GUFI Service in local system provides the functionality of generating and tracking GUFIs.

- The Flight Object Service maintains an up-to-date version of all subscribed flight data. The flight data is organized into flight objects by GUFI and then stored in a database for continuous updates and queries.
- The Flight Data Validation provides validation and reporting on FIXM 4.0 based FF-ICE/1 messages conformance to schema and set of business rules. It also monitors FIXM messages and provides near real-time status (valid or invalid) to users on any findings related to non-conformance of schema and non-compliance to business rules.
- The Simulator of JCAB processes received FF-ICE/1 Flight Plan messages from eAUs. It also supports publishing constraints with AIXM and iWXXM messages and submitting the response that includes the constraints to eAUs.
- The Simulators of ANA and JAL generate FF-ICE/1 Flight Plan messages and submit Trail Requests and updated Flight Plans according to the constraints provided by eASPs.

4.2 Message Process

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.

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

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 decision tree of process flow for the message of Preliminary Flight Plan (E_PFP) is shown in Figure 4. If the message can be processed and is free of syntax errors, a Submission Response of ACK will be responded by eASPs. And then, each eASP will check the constraints and publish Planning Status (PLAN_STATUS) to the eAU for the received E_PFP message. There are three status options in the PLAN_STATUS message: NON-CONCUR, NEGOTIATE, and CONCUR. Due to the different operation situations, different eASPs will have different specific implementations. For example, one eASP may define a constraint type as Non-Concur while another eASP may define that same constraint type as Negotiating.

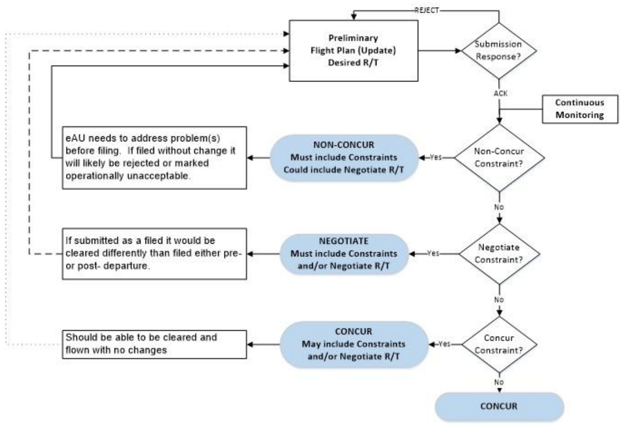

Fig. 4. Process Flow for E_PFP

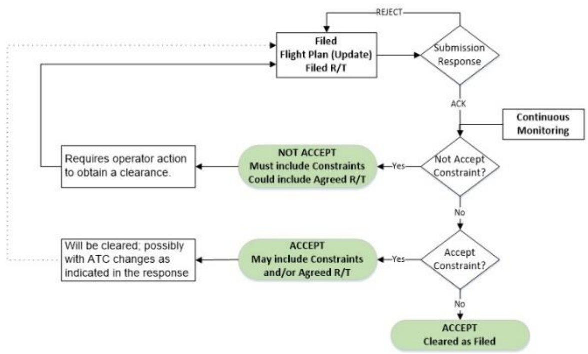

Fig. 5. Process Flow for E_FPL

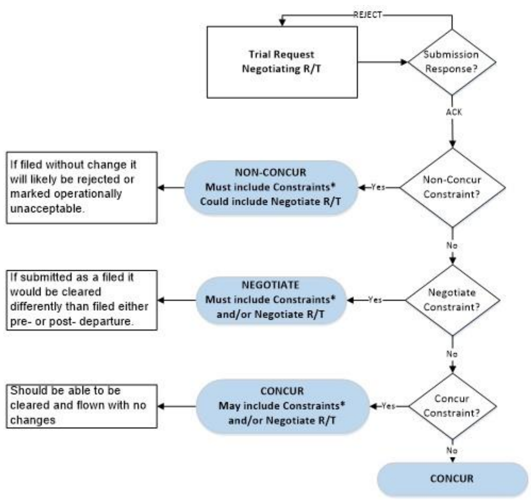

Fig. 6. Process Flow for E_TRIAL_REQ

And the process flow for the Filed Flight Plan is shown in Figure 5. After getting Concur for Preliminary Flight Plan from all three eASPs, it is available for eAU to publish Filed Flight Plan (E_FPL). According to the continuous monitoring, each eASP continuously checks the constraints that will affect the Filed Flight Plan in its own managed airspace and publish Filing Status (FIL_STATUS) to the eAU. There are two status options in the FIL_STATUS message: NOT ACCEPT and ACEPT.

As shown in Figure 6, the Trial Request is utilized for negotiation between eASP and eAU. In this scenario, when JAL received the message of Filing Status Update with departure fix constraint from the FAA, the Trial Request message was used to determine whether a departure over another route would be acceptable. And the Trial Response message with Concur is returned from the FAA.

4.3 Validation and Analysis

The validation of flight information exchange model (FIXM 4.0) implementation is an essential component of the 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 message based operations of JAL and JCAB for the KJFK-RJAA vignette are shown in Figure 7 and 8.

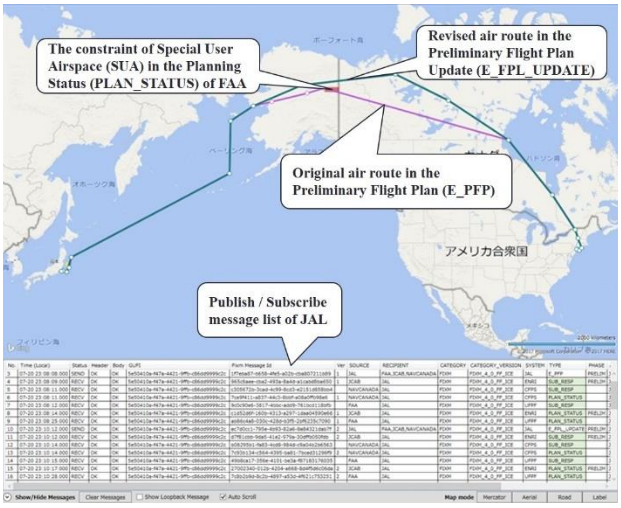

Fig. 7. JAL Simulator

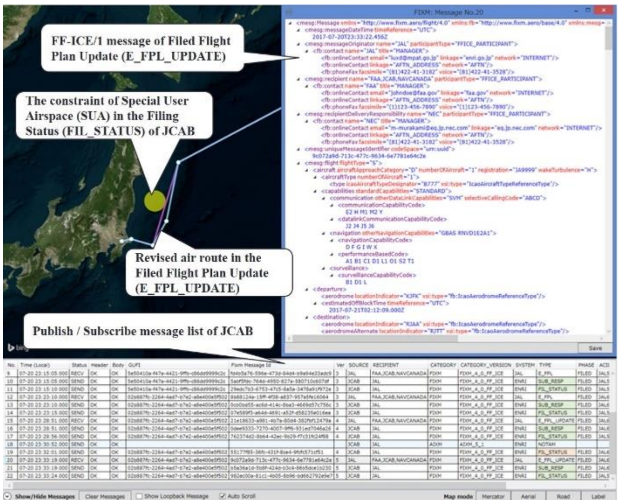

Fig. 8. JCAB Simulator

In the FF-ICE/1 messages, there are two parts (Figure 8). 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.

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, reginal and global areas.

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

For standards-based interoperability, the routing standards between different systems to ensure message delivery should be addressed. 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. For example, translating 4D points to ATS route text. For 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 in different ways.

Finally, in order to evaluate the local communication performance, the message sending time and receiving time of JAL, JCAB and NEC are recorded. Since there is an error for Windows operation system based synchronization among distributed computers, the following method is applied to calculate the communication time (T_C) between JAL and JCAB.

$$T_{JAL} = T_{JCAB} + \Delta T \quad (1)$$

$$T_{JCAB\_IN} - T_{JAL\_OUT} = T_C - \Delta T \quad (2)$$

$$T_{JAL\_IN} - T_{JCAB\_OUT} = T_C + \Delta T \quad (3)$$

$$T_R = T_{NEC\_IN} - T_{NEC\_OUT} \quad (4)$$

where ΔT is the synchronization error of current time between the JAL Simulator (T_{JAL}) and the JCAB Simulator (T_{JCAB}), and T_R is the message routing time in SBN. Then T_C can be calculated as:

$$T_C = [(2) + (3)]/2 \quad (5)$$

Based on the results of 100 tests during the different time frames, the average communication time between JAL and JCAB is 322nm in which the average local message routing time in SBN is 151nm. Even the communication time over Internet cannot be assured, there is no significant delay during the tests and the communication time in this level is possible to satisfy the general requirement of eAUs and eASPs for FF-ICE/1 operation.

5 Conclusion

In this paper, the overview of IIH&V international project for validating FF-ICE/1 oriented operation is introduced. And the observations and analysis of validation exercises consisting of Tabletop exercises and Lab exercises 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/1 provision implementation between ASPs, AUs, and aviation stakeholders are clarified. Finally, the problems and challenges for constructing the FF-ICE/1 operating environment are discussed.

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