SESAR SWIM Global Demonstrations Lessons Learned

Abstract
As part of a sequence of global SWIM events, amongst these also the recently conducted FAA NextGen’s Mini Global II and the ICAO APAC workshop in Bangkok, at the ENAV prototype systems center, Rome ACC Italy, on the 8th and 9th of June, SESAR has conducted a SWIM Global Demonstration.

This document elaborates in high detail on the various aspects of SWIM, as experience during the preparation of the SESAR SWIM Global Demonstration. As the SESAR SWIM Global Demonstration validated the global applicability of SWIM, this feedback is primarily intended to serve as input for further improvement of SWIM.
SESAR SWIM Global Demonstrations
Lessons learned

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Document History

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<tr>
<td>00.00.05</td>
<td>13/09/2016</td>
<td>Chapter 2 added</td>
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<tr>
<td>00.01.00</td>
<td>04/10/2016</td>
<td>FINAL</td>
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<td>Include proposal for ownership of recommendations</td>
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<tr>
<td>00.01.01</td>
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<td>FINAL</td>
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Executive summary

As part of a sequence of global SWIM events, amongst these also the recently conducted FAA NextGen’s Mini Global II and the ICAO APAC workshop in Bangkok, at the ENAV prototype systems center, Rome ACC Italy, on the 8th and 9th of June, SESAR has conducted a SWIM Global Demonstration.

The SESAR SWIM Global Demonstration event brought together more than 150 visitors to see first-hand more than 40 organisations from across world regions, besides many partners from all across Europe, including United States, Australia, United Arab Emirates, Mongolia and Brazil.

During the SESAR SWIM Global Demonstration, through a series of joint interoperability demos, the SGD partners showed the technical feasibility of connecting different local implementations of SWIM, exchanging information in areas such as aeronautical, meteorological, and flight and network information through globally common SWIM standards.

Partners contributing to the technical demonstrations included Air Services Australia, Atech, Austro Control, Avitech, Boeing R&T Europe and Jeppesen, Brazilian Airspace Control System Implementation Commission (CISCEA), Brazilian Department of Airspace Control (DECEA), Civil Aviation Authority of Mongolia (MCAA), Comsoft, Dubai Air Navigation Services (DANS), DSNA, Emirates Airlines, ENAV, EUMETNET, Eurocontrol, FAA, Frequentis, Honeywell, Ingegneria Dei Sistemi S.p.A. (IDS), Leonardo – Finmeccanica, Luciad, Meteo France, NAV Portugal, Qantas, Saipher ATC, SESAR Joint Undertaking, TAP Portugal, Thales, TOPLINK, UAE General Civil Aviation Authority (GCAA), UAE National Centre for Meteorology and Seismology (NCMS).

This paper elaborates in high detail on the various aspects of SWIM that were validated during the preparation of the SESAR SWIM Global Demonstration:

- Stakeholder collaboration
- Technical infrastructure
- Services
- Data models
- Operational view
- Business view
- Next steps

As the SESAR SWIM Global Demonstration validated the global applicability of SWIM, this feedback is primarily intended to serve as input for further improvement of SWIM.
1 Introduction

1.1 Purpose of the document, intended readership

This report elaborates in high detail on the various aspects of SWIM that were validated during the preparation of the SESAR SWIM Global Demonstration. As the SESAR SWIM Global Demonstration validated the global applicability of SWIM, this feedback is primarily intended to serve as input for further improvement of SWIM.

The report is intended to feedback on SWIM to the SESAR members, to the European SWIM stakeholders, to the SESAR SWIM Global Demo international partners, and to the ICAO Information management panel (IMP).

1.2 Acronyms and Terminology

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<thead>
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<th>Term</th>
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<tr>
<td>ACI</td>
<td>Airports Council International</td>
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<td>AIRM</td>
<td>ATM Information Reference Model</td>
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<td>AIXM</td>
<td>Aeronautical Information Exchange Model</td>
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<td>API</td>
<td>Application Protocol Interface</td>
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<td>ASA</td>
<td>Air Services Australia</td>
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<td>ATS</td>
<td>Air Traffic Service</td>
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<td>ATM</td>
<td>Air Traffic Management</td>
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<tr>
<td>B2B</td>
<td>Business to business</td>
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<td>CISCEA</td>
<td>Brazilian Airspace Control System Implementation Commission</td>
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<td>DANS</td>
<td>Dubai Air Navigation Services</td>
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<td>DECEA</td>
<td>Brazilian Department of Airspace Control</td>
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<tr>
<td>DSNA</td>
<td>Air Navigation Service Provider of France</td>
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<tr>
<td>EAD</td>
<td>European AIM database</td>
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<td>E-ATMS</td>
<td>European Air Traffic Management System</td>
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<td>ENAV</td>
<td>Air Navigation Service Provider of Italy</td>
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<td>FAA</td>
<td>Federal Aviation Agency (USA)</td>
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<td>FIXM</td>
<td>Flight Information Exchange Model</td>
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<td>Flight Management System</td>
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<td>GML</td>
<td>Geography Markup Language</td>
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<td>Globally Unique Flight Identifier</td>
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<td>International Air Transport Association</td>
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<td>SWIM</td>
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<td>UUID</td>
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<td>WXXM</td>
<td>Weather Information Exchange Model</td>
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<td>XML Schema Definition</td>
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2 Summary of Recommendations

SECTION 3: STAKEHOLDER COLLABORATION

Recommendation #01 [Registry]
Proposed ownership: FAA, SESAR, others to investigate, and report to ICAO\IMP through Working Papers

- Continue enhancement of the registries to facilitate service discovery and initiate service connectivity.

SECTION 4: TECHNICAL INFRASTRUCTURE

Recommendation #02 [SWIM TI Messaging Technologies]
Proposed ownership: FAA, SESAR, others to investigate, and report to ICAO\IMP and ICAO\COMMUNICATIONS panel through Working Papers.

- Create an overview of interoperable standards based SWIM TI messaging and combinations thereof, the type of needs they satisfy and the complexity to deploy, operate and maintain such messaging at a global/interregional scope.
- Evaluate the need to profile interoperable standards based messaging at a global/interregional scope
- Evaluate interoperable standards based messaging in a large scale context

Recommendation #03 [Connections and Throughput]
Proposed ownership: IMP to have a debate where TI material needs to be maintained [#03, #08, #09, #10, #23, #34]

- Consider filtering to limit the message throughput to the participants that cannot handle high levels of throughput

Recommendation #04 [Security – Layers and Combination]
Proposed ownership: FAA, SESAR, others to investigate, and report to ICAO\IMP and ICAO\COMMUNICATIONS panel through Working Papers. Potentially validate through additional global demonstrations [#04, #05, #06]

- Demonstrate the operational need for strong security at message level and demonstrate one or more interoperable standards based solutions at a global/interregional scope.
- Create an overview of interoperable standards based security controls and combinations thereof, the type of needs they satisfy and the complexity to deploy, operate and maintain these controls at a global/interregional scope.
- Analyse and elaborate on security versus safety at a global/interregional scope.

Recommendation #05 [Security - Trusts]
Proposed ownership: FAA, SESAR, others to investigate, and report to ICAO\IMP and ICAO\COMMUNICATIONS panel through Working Papers. Potentially validate through additional global demonstrations [#04, #05, #06]

- Elaborate on operational benefits, costs and risks of trust mechanisms at a global/interregional scope.
- Analyse and elaborate on concrete non-mandatory trust mechanisms at a global/interregional scope including legal interoperability matters.
- Categorise the operational needs and document candidate concrete trust mechanisms at a global/interregional scope.
Recommendation #06 [Security - IP Networks]
Proposed ownership: FAA, SESAR, others to investigate, and report to ICAO\IMP and ICAO\COMMUNICATIONS panel through Working Papers. Potentially validate through additional global demonstrations [#04, #05, #06]

- Since access to information is obtained by accessing the services behind the firewall, a streamlined process is needed to shorten the time from the request for access is received and the time access is granted.
- Capability for systems to work with VPN’s, credentials, certificates and over the internet is necessary for full interoperability. A strong network team is needed to establish and maintain connections with other partners and be able to adapt configurations as necessary. A system that will allow for connecting new partners to services has to be simple and time efficient, perhaps somewhat automated.
- Considering multiple failures and/or difficulties, there is a need to dig further in causes and possible remedies
- Analyse the VPN related difficulties and identify improvements

SECTION 5: SERVICES

Recommendation #07 [API]
Proposed ownership: IMP to incorporate in ICAO provisions

- A suggestion would be to break up the services into smaller logical components, or breaking up the documentation into smaller service based components.

Recommendation #08 [Publish Subscribe]
Proposed ownership: IMP to have a debate where TI material needs to be maintained [#03, #08, #09, #10, #23, #34]

- Considering the many variations on the notion Publish/Subscribe that have operational significance, define a minimum set of shared Publish/Subscribe related terminology.
- Whereas the definition of globally standardized subscription management interface/contract may be too ambitious, it may be useful to issue recommendations to increase reuse.
- Whereas the definition of globally standardized data delivery interface/contract may be too ambitious, it may be useful to issue recommendations to increase reuse.
- Whereas not all messaging technologies natively support inclusion of meta-data as used through AMQP 1.0, it may be useful to issue recommendations to standardize some of these meta-data elements.
- AMQP broker configurations could have a set of standardized configurations so as to avoid having to send unnecessary heartbeats.

Recommendation #09 [WFS]
Proposed ownership: IMP to have a debate where TI material needs to be maintained [#03, #08, #09, #10, #23, #34]

- Identify a set of common WFS requests for Aviation domains.
- Document and make available in a Donlon like manner, sample generic WFS query text for such requests using GML based schemas (e.g. AIXM 5.1 and 5.1.1, DNES 1.0 and 2.0, IWXXM 1.0, 1.1 and 2.0). Such requests can be used by a WFS service provider to perform a quick self-assessment and serve as examples for a service consumer as well.

Recommendation #10 [Data-centric vs Event-centric]
Proposed ownership: IMP to have a debate where TI material needs to be maintained [#03, #08, #09, #10, #23, #34]
• Elaborate on operational needs of data-centric, event-centric and possibly other forms of information sharing at a global/interregional scope.
• Define/complete standardisation to allow information sharing in data-centric, event-centric and possibly other forms at a global/interregional scope.

Recommendation #11 [Absence in FIXM 3.0.1]
Proposed ownership: FIXM CCB

• Elaborate on and identify the operational needs for flight related operations to be understood and standardised at a global/interregional scope.

Recommendation #12 [FF-ICE]
Proposed ownership: FIXM CCB

• Provide a clear mapping (concept -> logical and logical -> physical) between processes described in ICAO Doc 9965 and services based on the specifications of the future FIXM versions.

SECTION 6: DATA MODELS

Recommendation #13 [Compliance and Validation]
Proposed ownership: IMP to incorporate in ICAO provisions

• Systems should consider validation on reception and before sending. Services that don’t validate their messages run the risk of publishing invalid messages and not becoming aware of such invalid content and the consumers of such messages may error on reception and would never know without looking through logs. Another suggestion would be to provide direct feedback whenever schema validation failed.

Recommendation #14 [Business Rules]
Proposed ownership: IMP (AIRM) to define generic syntax, usage of business rules. Afterwards AIXM/WXXM/FIXM CCBs to apply [#14, #24, #28]

• All partners involved should understand what fields are mandatory to be included within each message type and a validation component is needed for each message interchanged to guarantee message compliance. Business rules should be made clear and easily accessible. Clear messaging when a message has erred should be provided in a response so partners can be alerted and fix any issues. Consolidate, working group to make these globally known.

Recommendation #15 [Meta-Data on the Format of the Data]
Proposed ownership: IMP to incorporate in ICAO provisions

• Register the XMs and their versions as MIME-types at IANA.
• Encourage the effective use meta-data on each message to indicate the format of the payload.
• Envisage the use of the standardised property "content-type" in the case of AMQP v1.0.

Recommendation #16 [Regional Extensions]
Proposed ownership: AIXM CCB, FIXM CCB

• Define a platform to host schemas and extensions for AIXM similar to what is available for FIXM (from an accessibility perspective).
• Ensure availability of versioned extensions on AIXM and FIXM platforms.
Recommendation #17 [FIXM 3.0.1 – Lack of Clarity / Consistency]
Proposed ownership: FIXM CCB

- The specifications of the future FIXM versions should provide an unambiguous, authoritative and exhaustive description of each information element and ensure a consistent behaviour throughout the specification.
- The specifications of the future FIXM versions should provide traceability from each information element to the rationale for its inclusion in the FIXM specification (e.g. a concept of FF-ICE).

Recommendation #18 [FIXM 3.0.1 – Aircraft Trajectory]
Proposed ownership: FIXM CCB

- Ensure a clear mapping between information described in Doc 9965 and the specifications of the future FIXM versions.

Recommendation #19
Withdrawn

Recommendation #20 [IWXXM - Unit of Measure]
Proposed ownership: WXXM CCB

- Ensure an unambiguous and exhaustive documentation of Unit of Measure to be used in IWXXM 2.0 and onwards.

SECTION 7: OPERATIONAL VIEW

Recommendation #21 [Multiple models]
Proposed ownership: IMP AIRM and AIXM/WXXM/FIXM CCBs to fix it [#21, #22]

- Make an exhaustive inventory of overlaps in the models.
- Elaborate on the role the AIRM can/needs to play to provide unambiguous clarity on the compatibility of elements from distinct models and the impact thereof.
- Elaborate on a coordination method on overlaps for the distinct governing bodies of the distinct models.

Recommendation #22 [Cross Model Referencing]
Proposed ownership: IMP AIRM and AIXM/WXXM/FIXM CCBs to fix it [#21, #22]

- Make an exhaustive inventory of possible cross model references
- Elaborate on a coordination method on cross model referencing for the distinct governing bodies of the distinct models

Recommendation #23 [Data Loops/Echoes]
Proposed ownership: IMP to have a debate where TI material needs to be maintained [#03, #08, #09, #10, #23, #34]

- Elaborate on the risks of unwanted data loops and unwanted echoes possibly transformed, and how they can be avoided/mitigated

Recommendation #24 [Business Rules/Processes]
Proposed ownership: IMP (AIRM) to define generic syntax, usage of business rules. Afterwards AIXM/WXXM/FIXM CCBs to apply [#14, #24, #28]
- Elaborate on priority and possibility to capture business rules/business process currently expressed in plain text as IT ingestible/digestible artefacts using open standards based languages.
- Provide such IT ingestible/digestible artefacts.

**Recommendation #25 [Testing of operational System]**
Proposed ownership: SGD participants

- Elaborate and underline the value of SWIM as a catalyst for the ability to test operational grade legacy systems when such systems are exposed à la SWIM in particular in global interoperability testing context.

**Recommendation #26 [Timeline]**
Proposed ownership: IMP members to assess appetite for future demonstrations

- Future global demonstrations should include collaboration on strategic, pre-tactical and post arrival phases.

**Recommendation #27 [Weather - Beyond METAR, TAF, SIGMET]**
Proposed ownership: ICAO/MET panel

- Verify if there are operational needs for multidimensional weather data at a global/interregional scope.
- If established, elaborate on operational needs, benefits and costs for a standard exchange format for multidimensional weather data at a global/interregional scope.
- If established, analyse and elaborate on concrete standard exchange formats at a global/interregional scope for multidimensional weather data.

**Recommendation #28 [Data Quality and Business Rules]**
Proposed ownership: IMP (AIRM) to define generic syntax, usage of business rules. Afterwards AIXM/WXXM/FIXM CCBs to apply [#14, #24, #28]

- Elaborate on data quality issues and how they can be prevented and/or detected in an automated manner.
- Elaborate on business rules to ensure a shared interpretation of the weather domain.
- Elaborate on business rules to clarify delimitations and constraints, and to ensure a shared interpretation of embedded elements from AIS.
- Elaborate on business rules to clarify relationships with other models.

**Recommendation #29 [Flight Planning Phase]**
Proposed ownership: ATMRPP / anyone

- Highlight and demonstrate the operational value of SWIM in flight planning phase.

**Recommendation #30 [Flight Execution Phase]**
Proposed ownership: ATMRPP / anyone

- Elaborate on operational needs, benefits and costs for information sharing with the FMS at a global/interregional scope.

**Recommendation #31 [Multi-Master]**
Proposed ownership: ATMRPP
- Elaborate on and clarify required consistency, completeness and availability of flight related information and which components are expected to provide this functionality.

**Recommendation #32 [FlightStatus]**  
Proposed ownership: ATMRPP

- Elaborate on and clarify responsibilities of participants in information sharing on the FIXM FlightStatus or equivalent in futures versions of FIXM.

**Recommendation #33 [Flight Object]**  
Proposed ownership: FIXM CCB

- A set of metadata (headers) for the flight object needs to be agreed upon and enforced at some level. Headers need to be clear and not suggestive as inaccurate headers may lead to confusion.

**Recommendation #34 [Gufi]**  
Proposed ownership: IMP and ATMRPP to have a debate where these issues should be addressed [#03, #08, #09, #10, #23, #34]

- Explore if functionality to be provided by a Gufi service can be defined in generic manner supporting all legacy systems during a possibly long transition phase towards a global ATM that natively speaks Gufi.
- Provide recommendations on naming, operations and data structures for a Gufi service to maximize reuse across distinct instantiations and allowing for a versioned forward and backward compatible evolution.
- Examine opportunity to globally standardize a minimum contract that every Gufi service shall offer.
- Elaborate on legacy integration models and their pros/cons/risks.
- Elaborate on consistency issues and ways to avoid/mitigate.
- Ask IATA for their lessons learned from their operational use of a concept that is a similar to Gufi.

**Recommendation #35 [Global ATFM]**  
Proposed ownership: ATMRPP

- Make the value of SWIM in Global ATFM explicitly visible.

**Recommendation #36 [Data Inconsistency]**  
Proposed ownership: IMP to develop provisions ensuring proper synchronizing of data

- Synchronize the databases used for waypoints/fixes so that there are global reference points without any confusion.
- First, to conduct international demonstrations, producers will be required to populate the baseline data in a SNAPSHOT section in the AIXM message for NOTAMs.
- Long term, a solution needs to be developed where ASPs can share baseline data.
- Ensure that international baseline data defines airspace features consistently across ASPs.

**Recommendations #37 [AI Data Overlap]**  
Proposed ownership: IMP to develop provisions on usage and data origination

- Define an extensible ontology that allows to capture usages of data.
- Define means that allow to the usages to stay attached to the every instantiation of data as well as for a service to advertise the supported usages of the data it accepts and/or data it produces. Such means need to usable for automation. An example that reflects the expression of usage scope/purpose of usage very well, is the manner "key usage" and "extended key usage" are defined for X509v3 certificates:
There are intended as well as restrictive usages.
- There is a standardised list of pre-defined usages.
- The standardised list of pre-defined usages is extensible both within an overall scope as within a local scope.
- The usages are part of the data and always travel with the data.
- The usages are also part of the policy of the service that publishes the data.
- The data can have multiple usages.

- Clarify questions raised above on authoritative entity acting as data originator (creation).
- Clarify questions raised above on multiple authoritative entities acting as data provider (publication).
- Clarify delimitation of authoritative boundaries in order to be usable in an automated manner.

**Recommendation #38 [AI Identification and Referencing]**
Proposed ownership: AIXM CCB

- Clarify the "natural key" concept beyond "Feature Identification and Reference 1.0, Chapter 3.4.2 Using natural keys".
- Clarify variations of gml:identifier
- Clarify compositions
- Clarify identification and referencing in Digital NOTAM Event Specification and in the AIXM Temporality Concept

**Recommendation #39 [AI Digital Future]**
Proposed ownership: The ICAO|IMP

- Clarify the targeted "digital future" of AIS and distribution of responsibilities,
- Clarify transition phases towards the targeted "digital future" as such phases could take a long time and/or one such phase could even become a terminal state

**SECTION 8: BUSINESS VIEW**

**Recommendation #40 [Stakeholder Participation]**
Proposed ownership: IATA

- Analyse and identify the reasons of low active participation of Airlines and Airports
- Analyse and identify the reasons of the enthusiasm of SGD participating airlines to understand the value that SWIM brings to Airlines
- Re-assess if the current direction of SWIM really covers the most important operational needs of Airports and really brings value to the Airports

**Recommendation #41 [Value Chain]**
Proposed ownership: SESAR / anyone to report to IMP through Working Papers

- Elaborate on operational needs, benefits and costs for integration with other SWIM worlds such as IATA, ACI and OTA.
- Define/align standardisation for information sharing between SWIM and other directly neighbouring SWIM-like worlds.

**Recommendation #42 [Legacy Integration]**
Proposed ownership: ATMRPP

- Elaborate on operational needs, and business case blueprints of how they can moved to/integrated with the SWIM world in a step wise manner
Recommendation #43 [Automation]
Proposed ownership: ATMRPP / anyone

- Elaborate on operational needs and processes and how automation through SWIM can bring benefits at a global/interregional scope

SECTION 9: NEXT STEPS

Recommendation #44 [Global Interoperability Demonstrations]
Proposed ownership: Any potential demonstration participant

- Use the momentum and plan more global interoperability demonstrations
- Use future global interoperability demonstrations to validate new operational information exchanges, including FF-ICE/1
3 Stakeholder collaboration

3.1 General

Below are a few quotes from key-note speeches, relevant in the context of collaboration:

**Lt. Col. Jansen, Head of technical division of CISCEA, Brazil:** “DECEA has decided to cooperate with SWIM Global Demonstrations mainly for two reasons. The first one is that we consider it a strong test case for the applicability of the ICAO SWIM manual, ensuring that it is completely aligned to the GANP and the ASBUs. The second reason is that we foresee in the short term the possibility to apply the same methods of this demonstration to establish a real data flight information exchange process between DECEA and Eurocontrol for ATFM purposes. In order to represent Brazilian airspace DECEA has re-used with a few minor modifications the same system provided to MG-II. It is important to highlight that the flight plan and the track publications were done without any modifications in the FIXM message composition. From DECEA’s point of view that reinforces the fact that that development of FIXM, as well as other SWIM formats, is in the right track and will certainly help the main SWIM goal to be accomplished, which is to promote harmonisation and interoperability among ATC service providers.”

**Mr. Pierre Truter, Manager ICT planning, Air Services Australia:** “Let me start to explain why Air Services got involved in the SESAR Global Demo. Australia, as many of you, started on the road, as many of you, to implement the principles of SWIM in the technology environment of our organisation. There are always challenges when implementing. As the aviation industry involves into a more dynamic and complex environment, every part of the information and operational technology will start to converge. This approach calls for the undertaking of pilot projects or global demonstrations that promise swift realisation, offer tangible benefits, and represent a comparative low risk. Participating in these demonstrations are not only the traditional air navigation service providers but also the industry partners, and most important of all, our customers, the airlines. The lessons that we learn on these global demonstrations are invaluable for Air Services. To understand not only how the technology changes, but also how this will influence the future organisation. To understand the new skill sets that our staff will need in the future and to demonstrate the business value in the new services that we can provide to our customer.”

**Mr. Ahmed Al Jallaf, Assistant Director General, ANS of the United Arab Emirates:** “SWIM is the key technology enabling the necessary collaboration through the standardisation of open interfaces and the introduction of service oriented architecture, thus preparing us to post ATM to a new level where all stakeholders have access to detailed high quality information at real time. The SGD brought different stakeholders together, to demonstrate what SWIM would be able to achieve. In preparation of this demonstration, experts from various organisations and different expertise met together, engaging their minds, to make the demonstration happen on the practical level. This practical approach was fruitful, as it not only reveals what we can achieve today, but also what are the current gaps. By working together understanding theoretically how SWIM is designed has manifested in a real application. At the same level of importance was the exchange of minds from the experts with different backgrounds working together also on discussions beyond the scope of the demonstration. New ideas were discussed and formed new visions of the future of ATM… The GCAA recognises when participating to the SWIM Global Demo, as well as its involvement in the MG-II demonstration a few weeks ago, that it is necessary to make SWIM a key element in our ATM system landscape.”

**Mr. Jim Eck, assistant administrator for NextGen, with the FAA, USA:** “… I am very proud of our recent success with the FAA led Mini Global exercise in Florida. And I am pleased to the coordinated SESAR SWIM Global Demonstration, led by the SESAR Joint Undertaking in Rome this week. These two demonstrations showcase SWIM benefits, from a business, operational and technical perspective. Furthermore, they validate the ICAO SWIM concept of operations through actual global SWIM service development, including the SWIM registry. By working together, the FAA, SESAR and
other nations, are leading ICAO strategic vision on a globally connected seamless air traffic management system. Ultimately our goal is to support seamless interoperability and harmonisation, and to provide a mechanism for ANSPs and airspace users to make ATM systems more efficient."

Mr. Florian Guillermet, Executive Director SESAR Joint Undertaking: "What I want to stress is that this is really the spirit of SESAR, of making things happening with the industry, with the operational partners, and to get close to the operation… I am extremely honoured by the take-up that we have in this event, the number of participants from around the world, from all the different SWIM partners that we have on-board, here today in this room, but also through the live-streaming. You will see during this event a number of applications of SWIM which are not just European words. This SWIM demonstration is part of a chain of demonstrations, performed in the wide context of ICAO, in particular with a very strong cooperation with our colleagues from NextGen, FAA. This is a kind of sister-brother event with event that the FAA carried out a few weeks ago in Florida. This is the spirit what SWIM is about, to bring people together, to bring the aviation community together from around the world."

3.2 Usage of the registry

SWIM registries were available during the preparation of the demo, where partners can look for information they want to receive to facilitate system and service identification.

The registries were minimally used. This was because the services to be used had already been identified by stakeholders. Furthermore, the documentation for the services can get unwieldy and hard to pinpoint specific endpoints and parameters to be used. It was easiest to reach out to the point of contact to help provide a smaller, more direct document and instructions for connecting with the service.

- Neither NM nor its users use the Registry for the time being. All the information that NM users need on the NM B2B Services can be found in a dedicate site in the EUROCONTROL OneSky Online. This site is used as well as a collaboration platform in support of the NM B2B users. NM also has business and technical contact points to support the B2B users.

- The documentation about the FAA flight data service was provided by the FAA directly to the Network Manager. In the implementation phase, while FAA were also still implementing and testing, the collaboration between FAA and NM was quite effective, with quick feedback loops, and both FAA and NM implementations were ready on time and operational since April.

Recommendation #01 [Registry]

- Continue enhancement of the registries to facilitate service discovery and initiate service connectivity.
4 Technical infrastructure

Network Manager (EUROCONTROL): ‘The NM technical infrastructure in support of the SWIM Yellow Profile is operational since 2009. The use of the request/reply services was quickly adopted by the users, as it is very simple. The adoption of the publish/subscribe based services seems to take more time.’

Network Manager (EUROCONTROL): ‘FAA flight data is provided via the Publish/Subscribe paradigm of the SWIM Yellow Profile, using AMQP 1.0, in a similar way as NM. Therefore, the use of the FAA service was quite straightforward.’

4.1 Messaging

4.1.1 Messaging technologies

Due to the wide usage of open source messaging protocols like AMQP for publish-subscribe communication, adaption to consume from a source was straightforward and not overly complex. Web services were not heavily used, and instead all international interaction was done via publish-subscribe. FOXS WS & GUFI WS were ready and available out of the box was not used for any of the scenarios. Continuing usage of widely used, mature, open source messaging protocols is encouraged to facilitate global adaption and communication.

Four different messaging technologies have been used:

<table>
<thead>
<tr>
<th>Technology</th>
<th>MEP</th>
<th>Particularities</th>
<th>Security</th>
<th>Partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>OASIS AMQP v1.0</td>
<td>P/S</td>
<td>Push delivery Topic</td>
<td>SASL, TLS, X.509v3 certs, mutual</td>
<td>Boeing (P), DECEA (P,C), Eumetnet (P), Eurocontrol (including ASA) (P,C), Finmecanica (P,C), Harris/FAA (P,C), Indra (P,C), Thalesgroup (P,C)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Queue</td>
<td>VPN IP-source filtering Combination of above</td>
<td></td>
</tr>
<tr>
<td>OASIS WS-N 1.3</td>
<td>P/S</td>
<td>Pull delivery Topic</td>
<td>None</td>
<td>Eurocontrol (C), GCAA (P), IDS (P), Thalesgroup (C)</td>
</tr>
<tr>
<td>SOAP 1.1/SOAP 1.2</td>
<td>R/R</td>
<td>Synchronous</td>
<td>TLS, X.509v3 certs, mutual</td>
<td>Boeing (P,C), Eurocontrol (including ASA) (P,C), Harris/FAA (P,C), Thalesgroup (C)</td>
</tr>
<tr>
<td>HTTP/1.1</td>
<td>R/R</td>
<td>Synchronous</td>
<td>User/password VPN + User/password</td>
<td>Boeing (C), Eumetnet (P), Eurocontrol (C), Harris/FAA (P,C), Thalesgroup (?)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Includes REST-style</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In above table P and C stand for the roles of Publisher and Consumer respectively.

For none of the used messaging technologies a major interoperability problem has been encountered.

Both service providers and service consumers were typically created and available for use in a very short time (less than 1 week)
4.1.2 Connections and throughput

Some of the participants were not able to handle the high throughput and challenges were faced because partners would claim that messages were not received but in reality their system either dropped it or the message was queued waiting to be de-queued behind many other messages.

When throughput levels vary this widely, it is necessary to have a filtering capability in order to decrease message throughput to endpoints with limited capability. Filtering was done via content based routing to narrow down the flow to a more targeted group of messages and guaranteeing all messages needed were still received.

Thales has also tried to connect to GCAA but additionally to the technical problems, the security problems raised by network to network VPN prevented that.

For the sake of network efficiency, the publication of messages as a result of particular procedures within the context of a particular ANSP/region, should not reach external systems where they do not provide added value. E.g. the reception of delta messages on EU side (generated on US side), does not provide a real value since these messages are not fully formed.

4.2 Security

4.2.1 Layers & combination
Technologies for security controls at network, transport and message level have been used.

- Security controls at network level have created most difficulties/issues: VPN variations and/or IP-filtering
- Security controls at transport level were exclusively based on TLS.
- Security controls at network level were exclusively based on User/password, which can be considered as a weak protection even in combination with other security controls.

Combinations of security controls at different levels have been used.

The stronger/strongest forms of security controls at message level have not been used:

- In a SOAP based context, WS-Security allows the use of security controls at message level in a standardised manner as part of a protocol stack that can typically be handled entirely by mainstream middleware.

Recommendation #02 [Messaging Technologies]

- Create an overview of interoperable standards based messaging and combinations thereof, the type of needs they satisfy and the complexity to deploy, operate and maintain such messaging at a global/interregional scope.
- Evaluate the need to profile interoperable standards based messaging at a global/interregional scope
- Evaluate interoperable standards based messaging in a large scale context

Recommendation #03 [Connections and Throughput]

- Consider filtering to limit the message throughput to the participants that cannot handle high levels of throughput
- Other messaging technologies (REST style, any asynchronous messaging protocol such as AMQP 1.0) security controls at message level can be used in a standardised manner (e.g. XML Signature, XML Encryption, Open PGP, JOSE) as part of a protocol stack too but not necessarily supported out of the box by mainstream middleware.
- AMQP 1.0 based messaging can use sophisticated subsets of SASL to provide message level security in a standardised manner but currently adoption of such sophisticated subsets of SASL within AMQP 1.0 is low.
- Any form of messaging that has a fan-out of 1 to many (e.g. topic based, IP based multicast, application overlay based multicast) is confronted with additional difficulties to provide message level security that is specific for each possible receiver (e.g. parts of the message can only be read by some privileged receivers)

Despite absence of security controls at message level that support end-to-end security (such as electronic signature), from the perspective of the Eurocontrol systems, some interactions offered end-to-end security while other interactions offered only point-to-point security:

**Examples of point-to-point security**

FIXM 3.0.1 messages published by DECEA were forwarded by Thalesgroup systems to Eurocontrol systems. As no end-to-end security message level mechanisms (such as electronic signature) were in place and as the Thalesgroup systems acted as intermediary between DECEA and the Eurocontrol systems, these interactions were point-to-point interactions from the Eurocontrol perspective.

FIXM 3.0.1 messages published by INDRA were forwarded by Harris systems to Eurocontrol systems. As no end-to-end security message level mechanisms (such as electronic signature) were in place and as the Harris systems acted as intermediary between INDRA and the Eurocontrol systems, these interactions were point-to-point interactions from the Eurocontrol perspective.

**Examples of end-to-end security**

FIXM 3.0.1 messages published by FAA systems were forwarded by Harris systems to Eurocontrol systems. Despite absence of security controls at message level that support end-to-end security (such as electronic signature), such interactions were considered at the Eurocontrol side as secured end-to-end interactions based on TLS security controls because the forwarding Harris Corp. systems were considered to be FAA systems.

Flight related messages published by Airservices Australia systems were forwarded by Eurocontrol systems to other systems including Thalesgroup systems and other Eurocontrol systems. Despite absence of security controls at message level that support end-to-end security (such as electronic signature), such interactions were considered at the Eurocontrol side as secured end-to-end interactions based on TLS security controls as the forwarding Eurocontrol systems were considered to be Airservices Australia systems.

**Recommendation #04 [Security – Layers and Combination]**

- Demonstrate the operational need for strong security at message level and demonstrate one or more interoperable standards based solutions at a global/interregional scope.
- Create an overview of interoperable standards based security controls and combinations thereof, the type of needs they satisfy and the complexity to deploy, operate and maintain these controls at a global/interregional scope.
- Analyse and elaborate on security versus safety at a global/interregional scope.
4.2.2 Trusts

The TLS based services using X.509.v3 certificates for mutual authentication have allowed and handled the use of different types of issuer of the certificates:

- Self-signed
- Chain of issuers leading to a well-known Root CA
- Chain of issuers leading to a Root CA that is not well-known

In all cases the access could be given to the services based on the configuration of a trust. In all cases, this trust has relieved both the service provider and service consumer from part of the work needed to manage the authentication and allowed reuse of work already done in another context.

Recommendation #05 [Security - Trusts]

- Elaborate on operational benefits, costs and risks of trust mechanisms at a global/interregional scope.
- Analyse and elaborate on concrete non-mandatory trust mechanisms at a global/interregional scope including legal interoperability matters.
- Categorise the operational needs and document candidate concrete trust mechanisms at a global/interregional scope.

4.2.3 IP networks

Some of the European services that were available over the internet had to approve ports and IP addresses of the connecting services to connect to the US systems. This took longer than expected and introduced delays when meeting deadlines, specifically for connectivity testing.

In some cases the default VPN setup was not ideal for partners. Some partners have systems that run and connect to multiple services and they may need to connect to several VPN’s and still have access to the internet. For some of these European services, Harris had to establish split tunneling on some VPN connections to enable those participants to access other services on different networks via the same machine while connected to the VPN.

Since split tunneling opens up a network to certain vulnerabilities, it is not ideal for it to be enabled. The solution used on the US side was to deploy applications and routes on separate virtual machines that each were able to use different VPN’s. It is ideal because one system is never using more than one VPN connection, although it is flexible enough to use split tunneling if necessary.

The difficulties encountered at the Eurocontrol side with the use of VPNs during MG II were confirmed and remained unsolved.

Note: Eurocontrol Network Manager operational SWIM services are securely available over Internet with no need for VPNs and no network difficulties were encountered by the Network Manager clients in using these services.

Additionally, a site to site VPN between Eurocontrol and GCAA could not be established in time for the SGD.
Recommendation #06 [Security - IP Networks]

- Since access to information is obtained by accessing the services behind the firewall, a streamlined process is needed to shorten the time from the request for access is received and the time access is granted.
- Capability for systems to work with VPN’s, credentials, certificates and over the internet is necessary for full interoperability. A strong network team is needed to establish and maintain connections with other partners and be able to adapt configurations as necessary. A system that will allow for connecting new partners to services has to be simple and time efficient, perhaps somewhat automated.
- Considering multiple failures and/or difficulties, there is a need to dig further in causes and possible remedies
- Analyse the VPN related difficulties and identify improvements
5 Services

5.1 Application Protocol Interface (API)

With an objective to provide documentation for systems and services that provides service details including endpoints, parameters, and credentials and try make it less daunting to commence data sharing with such system or service, the following issue was found:

API Documentation necessary to formulate web service calls was not always available via the registry but was easily attainable via point of contact. API documentation in some cases had to be reduced and explained in order to gain a quick focus of endpoints tailored to the scenario. Some API documents were more than 200 pages and that makes it difficult to pinpoint the exact methods and parameters necessary for correct service interaction.

Recommendation #07 [API]

- A suggestion would be to break up the services into smaller logical components, or breaking up the documentation into smaller service based components.

5.2 Message Exchange Pattern (MEP)

5.2.1 Publish/Subscribe subscription management

A significant variety of mechanisms has been observed to manage subscriptions in MEPs that support some form of the Publish/Subscribe style. These mechanisms are typically situated in the application layer:

- Services, like for example Web Services Notification and Metgate. Web Services Notification is a true application layer service and its interface is entirely defined in terms of XSD and WSDLs. However it is not Aviation specific service.
- Dynamic subscriptions are active in a matter of seconds after manifestation of interest
- Static subscriptions have a significant delay, for instance 1 hour or more, that must be observed before subscriptions are active

Some of these mechanisms were entirely manual, agreed over WebEx, over phone, over email.

5.2.2 Publish/Subscribe data delivery

The technology to deliver the data was typically based on either SOAP or AMQP 1.0.

A significant amount of data was delivered in the form of single feature instance as a payload. Not all schemas lead to an interpretation that allows some of these feature instances to act as a root element of an XML document. This is typically linked with the fact that such feature are not defined as global element in the schema

In some cases the payload was part of a proprietary envelope; proprietary non re-usable parsing.

A significant amount of data was delivered with meta-data using the messaging technology. None of this meta-data is part of the XM standards. This meta-data has created a useful complement in many cases. Not all messaging technologies support this meta-data. AMQP 1.0 does: such meta-data can be accessed through a non-JMS API as well as through the JMS API.
In some cases a more complex and proprietary 2 step mechanism was required in order to fetch the data. The 2 steps consisted of a push followed by pull using information provided in the push payload. Examples include NMOC AI data in AIXM 5.1 (eAMI, AirspaceStructure - NAT) and MetGate Weather data in IWXXM 1.0.

Some connections to AMQP brokers were sometimes interrupted due to inactivity. In order to avoid having to restart whenever a connection closure due to inactivity occurs, a heartbeat message was agreed to be exchanged every 30 to 60 seconds. This avoids encountering connection closures due to inactivity. The heartbeat message was not globally necessary as many systems managed to stay connected with no activity for extended periods.

### Recommendation #08 [Publish Subscribe]

- Considering the many variations on the notion Publish/Subscribe that have operational significance, define a minimum set of shared Publish/Subscribe related terminology.
- Whereas the definition of globally standardized subscription management interface/contract may be too ambitious, it may be useful to issue recommendations to increase reuse.
- Whereas the definition of globally standardized data delivery interface/contract may be too ambitious, it may be useful to issue recommendations to increase reuse.
- Whereas not all messaging technologies natively support inclusion of meta-data as used through AMQP 1.0, it may be useful to issue recommendations to standardize some of these meta-data elements.
- AMQP broker configurations could have a set of standardized configurations so as to avoid having to send unnecessary heartbeats.

### 5.3 Web Feature Service (WFS)

Consumption of data from four distinct WFS service providers has been attempted with the WFS client functionality in Jumpstart in order to integrate the provided information in distinct demonstration scenarios but three failed. For 2 out of 3 failed cases, the root cause was diagnosed at the side of the WFS service. In one case out of 3 failed cases, there has not been enough time and resources available to perform the root cause analysis.

In 2 of these 3 failed cases, the objective was to recuperate various AIXM 5.1 feature instances for a particular airport:

- All feature instances related to a Digital NOTAM for a Runway contamination and that were needed to be able to draw the impacted elements.
- All feature instances related to a particular Airport using a bounding box filter

### Recommendation #09 [WFS]

- Identify a set of common WFS requests for Aviation domains.
- Document and make available in a Donlon like manner, sample generic WFS query text for such requests using GML based schemas (e.g. AIXM 5.1 and 5.1.1, DNES 1.0 and 2.0, IWXXM 1.0, 1.1 and 2.0). Such requests can be used by a WFS service provider to perform a quick self-assessment and serve as examples for a service consumer as well.
5.4 Flight related services

5.4.1 Data centric vs event-centric

The flight object model and its realization are understood and performed in different ways.

The data-centric approach whereby information is continuously consolidated into a current complete view satisfies the needs for a number of operational scenarios.

However, other operational scenarios require an event-centric approach. This has become very clear in the mapping of one way FIXM 3.0.1 messages distributed via a P/S interaction pattern on one side and the event-centric approach of the NMOC having an interface to enter departure, arrival, etc events and in the other way around for the NMOC to publish reports on status changes such as departure, arrival, change, etc.

Some ad-hoc heuristics have been developed to be able to perform such mapping to some extent in an automated manner. Simplified example: when a data-centric message enters with the actual time set in the runwayPositionAndTime for the FlightDeparture element and there is meta-data property MESSAGE_TYPE set to DEPARTURE, then that is interpreted as a signal to activate the FlightDeparture operation at the NMOC side. This is formally not correct for multiple reasons and is unacceptable from an operational perspective but was the best approximation that could be found to make the demonstration work.

**Recommendation #10 [Data-centric vs Event-centric]**

- Elaborate on operational needs of data-centric, event-centric and possibly other forms of information sharing at a global/interregional scope.
- Define/complete standardisation to allow information sharing in data-centric, event-centric and possibly other forms at a global/interregional scope.

5.4.2 Operations: absence in FIXM 3.0.1

The FIXM 3.0.1 model does not provide any standardisation on any flight related operation.

In contrast to AIXM 5.1 and IWXXM 1.0 based information that can be served with a standardised set of generic operations in a conformant manner via WFS, FIXM 3.0.1 based information cannot be exchanged in a conformant manner through WFS as there is no mapping of the FIXM 3.0.1 logical model to a GML based physical exchange model: there is only one FIXM 3.0.1 physical exchange model and it is not GML based.

Moreover a flight object goes through many more states and evolutions in many more possible variations initiated by many more participating systems than an AIXM 5.1 feature instance or IWXXM 1.0 feature instance.

Every flight related operation has required the ad-hoc definition and agreement between the involved Partner on how to encapsulate and use FIXM 3.0.1 to perform the operation in a manner understood the same way by all involved Partners.

It is assumed that the FF-ICE Implementation guidance (documented as a new chapter of ICAO Doc 9965) will provide standardisation of flight related operations.
Recommendation #11 [Absence in FIXM 3.0.1]

- Elaborate on and identify the operational needs for flight related operations to be understood and standardised at a global/interregional scope.

5.4.3 Flight and Flow Information for a Collaborative Environment (FF-ICE)

In the context of all demonstrations except for one (KATL - LIMC), the flight was submitted to one ASP entity which forwarded the information to all other involved ASP entities through a one way message. There were no means for FOC and for the ASP entity to which the flight was initially submitted to know whether the flight plan was acceptable for all other involved ASP entities.

Only in the case of KATL - LIMC, the flight was submitted to all involved ASP entities and only when all involved ASP entities agreed, the flight plan was considered valid.

It is assumed that the FF-ICE Implementation guidance (documented as a new chapter of ICAO Doc 9965) will provide standardisation of flight related operations at a logical level only and that it will not specify the physical contract. It is assumed that such illustrative examples of physical contracts will be provided through a FIXM Implementation guidance package.

Recommendation #12 [FF-ICE]

- Provide a clear mapping (concept -> logical and logical -> physical) between processes described in ICAO Doc 9965 and services based on the specifications of the future FIXM versions.

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1 ICAO Doc 9965: Manual on Flight and Flow Information for a Collaborative Environment (FF-ICE)
6 Data models

6.1 General

6.1.1 Compliance and validation

With the objective to share data internationally in globally used format, usage and understanding of agreed upon schemas is important so that global communication with minimal adaption is possible. Since all partners were using FIXM, AIXM and iWXXM, messages were understood with no need for adaption.

AIXM has an extension mechanism. Validation needs to know the extension scheme, it is possible to decode the AIXM core information of a message containing extension with an AIXM core parser (extension is unknown and ignored). A policy has to be defined in case of a validation error, use the message (even partially) or reject it.

Recommendation #13 [Compliance and Validation]

- Systems should consider validation on reception and before sending. Services that don't validate their messages run the risk of publishing invalid messages and not becoming aware of such invalid content and the consumers of such messages may error on reception and would never know without looking through logs. Another suggestion would be to provide direct feedback whenever schema validation failed.

6.1.2 Business rules

Some systems have business rules that messages need to comply with in order for them to be accepted. Other systems don't have any rules beyond valid schema. It is important to know which systems do have business rules and what those business rules are in order to avoid surprises when sending flight plans, flight objects and other message types. The business rules are not global but region or partner specific but in order to satisfy global information sharing effort has to be made to comply with those rules. Apart from the business rules are the agreed upon fields to be contained within each message type.

Recommendation #14 [Business Rules]

- All partners involved should understand what fields are mandatory to be included within each message type and a validation component is needed for each message interchanged to guarantee message compliance. Business rules should be made clear and easily accessible. Clear messaging when a message has erred should be provided in a response so partners can be alerted and fix any issues. Consolidate, working group to make these globally known.

6.2 Meta-data on the format of the data

XML payloads from a variety of schemas (AIXM 5.1, FIXM 3.0.1, iWXXM 1.0) were distributed through the messaging system and sometimes through the same messaging channel. The development work, elapsed execution time and computing resources needed to discover which
schema is applicable to the payload in each message can be entirely annihilated by using a form of meta-data.

Many messaging technologies provide one or more mechanisms that allow to inform the receiver of the format of the payload and/or to negotiate that format.

1. HTTP/1.1 provides the header Accept to indicate which formats are supported by the service consumer and the header Content-Type in the response informs the consumer on the format of the response. These headers are assumed to contain a MIME-type.

2. WFS provides the parameter outputFormat. There is no strict guidance on the values that are acceptable but it does not preclude the use of MIME types. The one single minimum mandatory value that must be supported by all conforming WFS implementation is a registered MIME-type.

3. AMQP v1.0 provides several mechanisms to inform the receiver of a message about the nature of the payload through any of:

   - The AMQP v1.0 type system
   - The standardized property "content-type". This property expects a MIME-type
   - An application property that is free to chose

Use of the standardised property "content-type" in AMQP v1.0 is highly intuitive and highly similar to HTTP/1.1.

<table>
<thead>
<tr>
<th>Recommendation #15 [Meta-Data on the Format of the Data]</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Register the XMs and their versions as MIME-types at IANA.</td>
</tr>
<tr>
<td>• Encourage the effective use meta-data on each message to indicate the format of the payload.</td>
</tr>
<tr>
<td>• Envisage the use of the standardised property &quot;content-type&quot; in the case of AMQP v1.0.</td>
</tr>
</tbody>
</table>

6.3 Regional extensions
Regional extension came in scope in the flight scenarios between FAA and SESAR in demo1, and during demo2.

6.3.1 European extensions
The ADR regional extension is used by the Eurocontrol NMOC services in the context of AI publications linked to:

   - The NATS (North Atlantic Track System)
   - The availability of Military Airspace

No support for the ADR regional extension was built in at the FAA consumer side:

   - It was decided to drop both use cases based on this extension from the scenarios because adaptation at the FAA consumer side required too much time and resources

6.3.2 FAA extensions
Several regional extensions are used by FAA services:

   - SubscriberFile for NASR 56 AIXM 5.1 publications
   - Metering for FIXM 3.0.1
   - SurfaceState for FIXM 3.0.1
   - FNSE for Digital NOTAM (AIXM 5.1)
Support for all these FAA regional extensions was built in at the European consumer side:

- The presence of Metering and SurfaceState data can be ignored in some cases and its presence will not necessarily create a problem for all consumer implementations but the presence of xsi:type in the data created a blocking problem at the European side
- In the case of the FOXS Request/Reply service the issue could have been circumvented by a reformulation of the request but that was considered too much work compared to adding support for the extension

Support for SubscriberFile and FNSE was necessary to access the data

There was not a reliable shared location to find the current versions of these extensions. Such locations could have been for instance:

- A registry or federation of registries
- A shared platform

### Recommendation #16 [Regional Extensions]

- Define a platform to host schemas and extensions for AIXM similar to what is available for FIXM (from an accessibility perspective).
- Ensure availability of versioned extensions on AIXM and FIXM platforms.

### 6.4 AIRM

Within the context of the SESAR SGD the AIRM is the cross domain reference to which the AIXM, FIXM and iWXXM have been mapped for SWIM information compliance purposes. These mappings are however strictly speaking outside the scope of the SESAR SGD activity. Yet this determines the choice to use the AIXM, FIXM and iWXXM as SWIM exchange models in the context of the SESAR SGD.

### 6.5 FIXM 3.0.1

**Network Manager (EUROCONTROL):** "The showcase demonstrated the exchange of flight data. For the exchange with FAA, the FAA model was used, for the exchange between NM and RocketRoute and DSNA the NM model was used. Both FAA and NM have plans to implement FIXM when it becomes enough stable for implementation."

#### 6.5.1 Lack of clarity/consistency

In the context of the demonstrations, the "ATS Message Content to FIXM Logical Model Map" has proven to serve as a highly reliable complementary reference on the interpretation and/or use of the FIXM 3.0.1 schema.

However a significant subset of FIXM 3.0.1 elements that fall outside of the scope of above document are not sufficiently clearly defined/documented to ensure a shared understanding by all involved Stakeholders.

**Example #1**

"OffBlockReadyTime/Estimated" versus FlightDeparture/standPositionAndTime/Estimated"
- "OffBlockReadyTime/Actual" and "OffBlockReadyTime/Target" have a specific text in the specification but "OffBlockReadyTime/Estimated" only has a generic text in the specification.
- "FlightDeparture/standPositionAndTime/Estimated" has a specific text in the specification that could be interpreted to have the exact same semantics as "OffBlockReadyTime/Estimated".
- Above ambiguity has led to 1 case of misaligned use of FIXM 3.0.1 from the Eurocontrol perspective.

**Example #2**

"OffBlockReadyTime/Estimated" as used in FAA Gufi Service versus "FlightDeparture/standPositionAndTime/Initial"

- "OffBlockReadyTime/Estimated" only has a generic text in the specification and is qualified in the context of FAA Gufi Service as "Original Date Departure Time".
- "FlightDeparture/standPositionAndTime/Initial" has a specific text in the specification that could be interpreted to have the exact same semantics as "OffBlockReadyTime/Estimated" within the context of FAA Gufi Service.
- Above difference in interpretation has led to 1 case of misaligned use of FIXM 3.0.1 from the Eurocontrol perspective.

**Example #3**

"FlightType/negotiating" versus "FlightType/agreed":

- The NMOC Flight Filing service was initially set up to expect a "FlightType/negotiating" trajectory in the request from an Airspace user and if the request was successfully honoured to return an "FlightType/agreed" trajectory.
- This was however not aligned with the expectations of the first effective user of the service who attempted to use a "FlightType/agreed" in the request. To avoid further difficulties the NMOC Flight Filing service was adapted to accept both "FlightType/negotiating" and "FlightType/agreed" in the request from an Airspace user.

**Example #4**

Altitude.XSD:

- The text accompanying Altitude.XSD indicates amongst others "Altitudes always record the actual numbers of feet/meters, even when the conventional notation is expressed in multiple tens of or hundredths", however the table and text in Chapter "7.1 Foundation:Altitude" of document "ATS Message Content to FIXM Logical Model Map" contradicts the above text accompanying Altitude.XSD.
- Because of the potential confusion the NMOC Flight Filing service explicitly documented its adherence to the convention documented in Chapter "7.1 Foundation:Altitude" of document "ATS Message Content to FIXM Logical Model Map".
- Nevertheless this was not clear and unexpected for the first consumer of the service, i.e., FAA who used the interpretation as provided in the text accompanying Altitude.XSD.
- FAA adapted its consumer to align with the specification of the NMOC Flight Filing service.
- The NMOC Flight Filing service was adapted as well to detect values multiplied by 100 and to reduce them automatically to the expected unit.
- Getting an aligned solution has required a significant amount of overhead.
- FAA and other partners maintained however to the text accompanying Altitude.XSD for other usages. This created a highly confusing mix of altitude values.

Typically as soon as a non-aligned interpretation of FIXM 3.0.1 elements was discovered with a consumer of a service, other consumers of the same service were subsequently and explicitly warned.
on possible diverging interpretations. In some cases non-aligned interpretations of FIXM 3.0.1 elements were tolerated if they did not have the effect of breaking a demonstration activity.

Recommendation #17 [FIXM 3.0.1 – Lack of Clarity / Consistency]

- The specifications of the future FIXM versions should provide an unambiguous, authoritative and exhaustive description of each information element and ensure a consistent behaviour throughout the specification.
- The specifications of the future FIXM versions should provide traceability from each information element to the rationale for its inclusion in the FIXM specification (e.g. a concept of FF-ICE).

6.5.2 Aircraft trajectory

In the context of one of the demonstrations (OMDB-LOWW), the current intentional trajectory calculated by the FMS was made available to various actors on the ground. It is not understood how/where this type of trajectory is captured in FIXM 3.0.1.

At the time of writing, it is assumed that the exchange of a trajectory calculated by the FMS, is not a requirement of FF/ICE/1.

In order to take advantage of the great potential that lies in knowing the trajectory of an aircraft, it is essential that the FIXM (flight object) message contains all vital parameters concerning the trajectory. The FIXM specification should be generic enough to encompass both airborne and ground-based prediction tools. Further it is important that the trajectory is updated continuously both on ground and in flight.

Once reliable and updated trajectories are available to the aviation community, development of processes to enhance efficiency and safety both within ATFM, ATC, Airports, Air Operators and also Aircraft manufacturers is expected to increase.

Recommendation #18 [FIXM 3.0.1 – Aircraft Trajectory]

- Ensure a clear mapping between information described in Doc 9965 and the specifications of the future FIXM versions.

6.6 AIXM 5.1

The FAA observed that there is no standard on whether positions are published in the order of lat/lon or lon/lat. The coordinate reference system (CRS) designated in the message is supposed to be used to establish the format for specifying positions, but some CRSs do not impose a strict order. For example, if the CRS designated is ESPG:4326, that CRS allows either order, so additional information needs to be added in the message to designate which order is being used. That is currently not supported, so during the MG II demonstration, we had to decide with our partners which order would be utilized.

Recommendation #19 [AIXM 5.1]

- Investigate the need for an element in the data schema where the order of lat/lon information can be specified for cases where it is not explicitly dictated by the CRS.
6.7 IWXXM 1.0

6.7.1 Unit of Measure

There is a generalised problem with clarity on the units of measure to use in IWXXM 1.0.

**Example**

Concrete examples from data exchanged during the demonstrations that raise major interoperability issues:

<iwxxm:speedOfMotion uom="knot">0</iwxxm:speedOfMotion>
<iwxxm:speedOfMotion uom="[kt_i]">30</iwxxm:speedOfMotion>
<iwxxm:meanWindSpeed uom="kn">3</iwxxm:meanWindSpeed>

IWXXM 1.1 suffers from the same problem.

The proposed standard IWXXM 2.0 RC1 provides more precision on Unit of Measure to use.

**Recommendation #20 [IWXXM - Unit of Measure]**

- Ensure an unambiguous and exhaustive documentation of Unit of Measure to be used in IWXXM 2.0 and onwards.
7 Operational view

7.1 Generic

7.1.1 Overlap between models

Multiple sources

Multiple sources exist for the same geographic area and/or flight.

Examples

- NASR 56, EAD worldwide minimum data set and NM B2B AIXM Data Sets all contain data for the same geographical area.
- NM B2B provides information on flights between its domain of responsibility and that of the FAA's domain of responsibility, and vice versa.
- FlightAware provides information on flight and flight positions for a number of geographical areas in the world whereas the local ANSPs also provide such information.

A number of generic concerns apply regarding the scope/purpose of usage, level of authoritativeness, conflicting information, multi-master, usability for automated handling. Such concerns are detailed in subsequent chapters dealing with specific domains.

Multiple models

The same feature is described in different models.

Examples

- IWXXM 1.0 describes Airspaces and Airports while AIXM 5.1 also does but they are not the same nor interchangeable. Are they mappable? If so how? Moreover they possibly have geometries in both models: what is allowed?
- FIXM 3.0.1 describes standardInstrumentDeparture and standardInstrumentArrival while AIXM 5.1 defines StandardInstrumentDeparture and StandardInstrumentArrival but they are not the same nor interchangeable. Are they mappable? If so how?
- IWXXM 2.0 RC1 has addressed this issue to some extent as described in "4.2.2 Data quality and business rules" by importing and reusing part of the AIXM 5.1 model.

Recommendation #21 [Multiple models]

- Make an exhaustive inventory of overlaps in the models.
- Elaborate on the role the AIRM can/needs to play to provide unambiguous clarity on the compatibility of elements from distinct models and the impact thereof.
- Elaborate on a coordination method on overlaps for the distinct governing bodies of the distinct models.
Cross model referencing

How can a flight in a FIXM x model reference an Airport in the AIXM 5.1 model? Use of UUID binds to a particular provider, and for the alternative "Natural key", there is no standard that defines whereof a natural key is composed.

Recommendation #22 [Cross Model Referencing]
- Make an exhaustive inventory of possible cross model references
- Elaborate on a coordination method on cross model referencing for the distinct governing bodies of the distinct models

Data loops/echoes

In the context of demo1, the Eurocontrol SWIM Jumpstart system was subscribed to a maximum of messages originating from all information providers involved in the demonstration, and the Eurocontrol NMOC system was subscribed to messages relevant for its DCB role only.

In this set up a number of unexpected phenomena were observed in a systematic manner:

- The Eurocontrol SWIM Jumpstart system received publications on weather directly from Eumetnet and unexpectedly also received these publications indirectly from the USA side. The latter were not the original Eumetnet messages but their expansion following the resolution of the 2 step publication.

- Following the successful filing of a flight plan, the Eurocontrol NMOC system published a single message to all interested participants. However shortly after this publication the Eurocontrol NMOC system unexpectedly received a number of distinct messages for the same flight from the USA side whereby the MESSAGE_TYPE took values such as DEPARTURE, ARR, etc. Moreover, had a particular functionality not been switched off (unintentional and accidentally) at the side of the Eurocontrol NMOC system that prevented subsequent update and re-publication due to such incoming messages, a permanent loop might well have come into existence.

Recommendation #23 [Data Loops/Echoes]
- Elaborate on the risks of unwanted data loops and unwanted echoes possibly transformed, and how they can be avoided/mitigated

7.1.2 Business rules/business processes

Somewhat related to "4.3.2 Operations: absence in FIXM 3.0.1" above but in much broader scope and for all domains: the discovery, the understanding and the use of business rules/business processes has proven to be a major area of difficulty and as corollary a huge opportunity for improvement. For example, obtaining the applicable business rules on departure time and/or arrival time as applicable in the NMOC systems has taken a number of elapsed days.
The major underlying root cause for these difficulties is the presence and description of the business rules/business processes in plain text in ICAO documents as well as regional documents (via the Doc7030 mechanism), requiring a human interpretation.

Availability of albeit only a subset of the rules/processes in such documents in an IT ingestible/digestible manner could from software/IT perspective hugely increase speed of development, decrease non-aligned interpretations, increase exhaustiveness, decrease human error, etc.

<table>
<thead>
<tr>
<th>Recommendation #24 [Business Rules/Processes]</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Elaborate on priority and possibility to capture business rules/business process currently expressed in plain text as IT ingestible/digestible artefacts using open standards based languages.</td>
</tr>
<tr>
<td>• Provide such IT ingestible/digestible artefacts.</td>
</tr>
</tbody>
</table>

7.1.3 Testing of operational system

A number of systems made available for the demonstrations were some form shadow system of true operations.

In at least six cases from six distinct Stakeholders, which are intentionally not named, the testing in the context of the preparation of the demonstrations revealed faults present in the operational software.

<table>
<thead>
<tr>
<th>Recommendation #25 [Testing of operational System]</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Elaborate and underline the value of SWIM as a catalyst for the ability to test operational grade legacy systems when such systems are exposed à la SWIM in particular in global interoperability testing context.</td>
</tr>
</tbody>
</table>

7.1.4 Timeline

In the context of the FF-ICE concept and the Global ATM Operational Concept, a number of different phases are defined on the timeline ranging from strategic, over pre-tactical and tactical up to archival.

The demonstrations have focused on the tactical phase only.

<table>
<thead>
<tr>
<th>Recommendation #26 [Timeline]</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Future global demonstrations should include collaboration on strategic, pre-tactical and post arrival phases.</td>
</tr>
</tbody>
</table>

7.2 Weather

7.2.1 Beyond METAR, TAF, SIGMET

METAR, TAF and SIGMET play an important role in Flight Planning. These three types of data are mainly used in forecasting operational needs and methods in order to conduct safe and legal flights. Their use in optimizing a flight is limited. The great benefit with digitizing these three types of weather
data lies mostly within the area of reducing workload through automation and enhancing human perception.

FAA in demo 1 (FAA Advanced weather product) and Eurocontrol in demo 2 (world-wide CB tops and extent) have shown only sideways newer weather related capabilities. Otherwise all the demonstrations have limited their demonstrated weather related capabilities to SIGMET and METAR, and some TAF.

Advanced weather products could have high relevance from an operational perspective, in particular for an Airline. For instance use of current multidimensional weather data over the Oceans to optimise a flight path in order to save fuel and/or win back time from earlier incurred delays.

Multidimensional weather data is a very important input also for optimizing a flight. Although there are a number of sources for achieving multidimensional weather data in today’s operations, it is a fair assumption that all consumers would benefit from digitized and standardized data of this type.

The XMs do not allow to share such multidimensional weather data. There are standards such NetCDF 4 (including HDF5) that allow to do that.

**Recommendation #27 [Weather - Beyond METAR, TAF, SIGMET]**

- Verify if there are operational needs for multidimensional weather data at a global/interregional scope.
- If established, elaborate on operational needs, benefits and costs for a standard exchange format for multidimensional weather data at a global/interregional scope.
- If established, analyse and elaborate on concrete standard exchange formats at a global/interregional scope for multidimensional weather data.

### 7.2.2 Data quality and business rules

There was a significant number of recurring issues with the quality of the data that was provided and/or its usability.

**Examples**

SIGMET, motion: a direction is provided but there is no speed. Not clear how is to be interpreted

**saf:Unit**, position: position at 0.0 latitude and 0.0 longitude. Not clear how is to be interpreted, but this location could not be correlated to the context

**saf:Unit**, designator: value XXXX, not clear how is to be interpreted

**saf:Aerodrome**, designator: values consisting of 5 numerical positions whereas there is an ICAO four letter location indicator for the intended Aerodrome

For some of the issues above, the IWXXM 1.0 schema provides some textual rules but they seem not to have been applied.

For other issues, the IWXXM 1.0 schema does not provide any rules.

**Example**

**saf:Aerodrome** and **saf:Airspace** do not contain a notion of temporality. Temporality is used at other location in the enclosing root IWXXM element.
- What if during the timespan of the enclosing root IWXXM element, for instance the geometry of the saf:Airspace changes?
- Should the single root IWXXM element then be broken into multiple root IWXXM elements?
- Should the geometry provided in the single root IWXXM element be considered as valid for the timespan of the enclosing root IWXXM element, irrespective of changes in the AIS domain?
- To what extent can AIS information as provided in AIXM 5.1 be related with the information provided in the IWXXM element in order to create a more complete situational awareness?

In flight planning the times of validity and the times of forecasted changes are of vital importance. These parameters are used in order to obey flight planning rules as laid down by the governing authorities. Hence all temporality parameters included in today’s legacy weather data must also be included in the digitized data.

The proposed changes in standard IWXXM 2.0 RC1 to replace saf by AIXM 5.1 does not solve this issue, as at the time of writing this report the embedded AIXM 5.1 validTime is ignored in the proposed standard IWXXM 2.0 RC1

**Recommendation #28 [Data Quality and Business Rules]**

- Elaborate on data quality issues and how they can be prevented and/or detected in an automated manner.
- Elaborate on business rules to ensure a shared interpretation of the weather domain.
- Elaborate on business rules to clarify delimitations and constraints, and to ensure a shared interpretation of embedded elements from AIS.
- Elaborate on business rules to clarify relationships with other models.

### 7.3 Flight

#### 7.3.1 Flight planning phase

In all demonstrations, a very significant element of the entire flight preparation phase has been shortcut by “the operator evaluates an alternative path”. These alternative paths were carefully prepared in the weeks and months before the actual demonstrations and the time spent and the coordination required to find these alternative paths ahead of the actual demonstrations are themselves proof of the amount effort and potential improvements that could be made.

The ability to take into account in an highly or fully automated manner a diversity of such things as not only basic weather and DNOTAMs, but also aircraft performance, regulations, measures, re-routings, flight-restrictions, etc, in the flight preparation phase has not been demonstrated.

**Recommendation #29 [Flight Planning Phase]**

- Highlight and demonstrate the operational value of SWIM in flight planning phase.

#### 7.3.2 Flight execution phase

The Boeing FMS was producing position information (first 50 times per second then once per second), flight path predictions (when there was a change) and the arrival message. All of this was captured by Jumpstar and shown but none of it was communicated.
The ability to obtain such information from the FMS was one of the few elements that demonstrated true, exhaustive and live Air-Ground communication in the demonstration and represented a significant new source of information.

### Recommendation #30 [Flight Execution Phase]

- Elaborate on operational needs, benefits and costs for information sharing with the FMS at a global/interregional scope.

#### 7.3.3 Multi-master

Information on a flight is produced by distinct sources and not necessarily in a predictable manner (e.g. order, moment of time). Hence information produced by multiple sources can conflict for a series of reasons such as quasi simultaneous production of information, not all sources have all information, not all sources have the most recent information, unavailability, bugs, ... In such case ingestion of information by a Stakeholder could lead to an inconsistent and/or incomplete view on a flight.

As an example and during the effective run of Demo1 at the Rome event, a Flight Departure message was issued by mistake at the FAA side for the flight LIMC-KATL a little more than 2 minutes before the regular Flight Departure message was issued by Milano Surface Management System. As the Eurocontrol NMOC system ingested information both from the FAA side and the Milano Surface Management System, the Eurocontrol NMOC wrongly marked the flight as departed and subsequently made this wrong information available to all subscribers.

The notion of consistency is used at many places in the current ICAO Doc 9965 but the notion is nowhere clearly defined and therefore the requirements are not clear and they are not unambiguous.

In distributed systems, there are many forms of consistency (e.g. weak consistency, eventual consistency, strong consistency, sequential consistency, atomic consistency, ...). Further, various forms of consistency interact with other characteristics such as various forms of availability and a solution typically represents a trade-off between such characteristics.

The current ICAO Doc 9965 and the draft additional FF-ICE Implementation Guide do not take ownership of the handling of consistency related to ensuring a shared common current picture amongst all relevant participants. These documents seem to remain at conceptual and logical level and seem to delegate these responsibilities to "the FF-ICE", applications and/or "SWIM".

However the notions of "the FF-ICE", applications and/or "SWIM" in such context are not clearly defined and the expectations of "the FF-ICE" and/or "SWIM" being able to ensure such consistency and/or completeness may be wrong.

### Examples

Section 2.3.1, g) in ICAO doc 9965 states "the data provide mechanisms for ensuring consistency, interoperability and persistence;" The expectations are not understood

Section 2.4.2 in ICAO Doc 996, paragraph under caption "Inconsistent flight information" states "None of these messages have version or sequence information, and often the messages are sent from origin to each service provider individually, and so adjacent service providers may have different information if they were to compare information". It is not understood how GUFI provides a solution for this.
Section 2.4.2 in ICAO Doc 9965, paragraph under caption "Information distribution" states "While FF-ICE must, by definition, impose requirements on how flight and flow information are communicated between ATM community members, these requirements are limited to the interface, and thus should not impose any restriction on how they individually store and process their data internally or mandate the use of any particular data model (such as a specific flight object).” Where can the "how" be found? Does the notion "interface" also include the service behavior that deals with ensuring consistency?

Section 4.5.3, c) in ICAO Doc 9965 states: "facilitate the ability of applications to ensure the overall consistency of information and data.". Can it be understood from this paragraph that the ultimate responsibility for consistency is expected to lie with the applications and not with SWIM?

**Recommendation #31 [Multi-Master]**

- Elaborate on and clarify required consistency, completeness and availability of flight related information and which components are expected to provide this functionality.

**7.3.4 FlightStatus**

FIXM 3.0.1 provides an element FlightStatus that itself includes as sub-elements various statuses for a single flight. During the demonstrations, some systems provided a value for instance for the FlightCycle sub-element in FlightStatus, other systems did not.

It is unclear which participant has which responsibility at what time and at which point of information sharing in the management of the lifecycle of any component of the element FlightStatus.

**Recommendation #32 [FlightStatus]**

- Elaborate on and clarify responsibilities of participants in information sharing on the FIXM FlightStatus or equivalent in futures versions of FIXM.

**7.3.5 Flight object**

At times flight object messages were confusing or misleading. Some international partners were not clear on the exact use of the message type headers and the messaging. An example would be when a sub-element in the departure element gets updated, the message header says DEPARTURE and a delta message is sent but this does not mean that the flight has actually departed.

**Recommendation #33 [Flight Object]**

- A set of metadata (headers) for the flight object needs to be agreed upon and enforced at some level. Headers need to be clear and not suggestive as inaccurate headers may lead to confusion.

**7.3.6 Global Unique Flight Identifier (GUFi)**

Multiple Gufi services were in scope: The Gufi service from FAA, the 3 distinct Gufi service instantiations using Jumpstart acting on behalf of NMOC, ASA and GCAA respectively. It is assumed that there was also a distinct Gufi service running for Brazil but there has been no direct visibility on or access to such service.
The presence of several GUFI services avoid to reach a full consistent scenario, since there is a small chance to generate the same ID by different providers, for different flights. Particular challenges observed in the context of the demonstrations:

Identifiers

Natural identifiers
The Gufi service from FAA as well as all Gufi service instantiations using Jumpstart (NMOC, ASA and GCAA) support a mapping a between one Gufi and one set of data elements. Although similar, the data elements selected to represent the natural identifier were not identical\(^2\). As a slightly different terminology for natural identifiers was used: The Gufi service from FAAs was based on metadata, the Gufi service using Jumpstart was based on GufiFlightObjectKeys.

Legacy identifiers
The Gufi service instantiations using Jumpstart (NMOC, ASA and GCAA) also support a mapping a between one Gufi and one or more legacy identifiers (IFPLID, FOID and SFPI respectively). The ability to capture multiple legacy identifiers in a single Gufi service can be useful in a situation where a flight involves multiple distinct legacy systems.

Lookup
Differences in the lookup service-capabilities were observed. The Gufi service from FAA, offers translations from 1 Gufi to 1 natural identifier, and from 1 natural identifier pattern to one Gufi and a natural identifier. All Gufi service instantiations via Jumpstart (NMOC, ASA and GCAA), offer translations from 1 Gufi to 1 natural identifier and all legacy identifier, from 1 natural identifier to 1 Gufi and all legacy identifier, from 1 legacy identifier to 1 Gufi, 1 natural identifier and all other legacy identifiers.

Change
Regarding change in the flight attributes, the Gufi service from FAA allowed for a change of all elements of the natural identifier with the exception of the original Departure Time+Date. The Gufi service instantiations via Jumpstart (NMOC, ASA and GCAA) also allowed all elements of the natural identifier to be changed with the exception of ADEP. Regarding the legacy identifier, additional legacy identifiers can be added.

Findings
The support by the distinct Gufi services for integration with legacy systems was similar but not identical. The support is assumed to reflect minimal needs for such integration for usability within the scope of the demonstrations but not necessarily to cover all needs for an operational use. The Gufi services did not all use the same naming, operations and data structures, whereas that could have been harmonized to some extent at least.

Legacy related consistency considerations

The additional activity to integrate Gufi handling with existing activity in a legacy system can be assumed not to be part of a single atomic action where all fails or all succeeds. Multiple distinct atomic actions may be required to align a Gufi service and a legacy system. Something may go wrong in each such action leading to inconsistency between the internal status of the legacy system and the status of one or more Gufi services.

\(^2\) Gufi service from FAA was based on ACID, ADEP, ADES, original Departure Time+Date, estimated Departure Time+Date, original Arrival Time+Date, estimated Arrival Time+Date. Gufi service using Jumpstart was based on ACID, ADEP, ADES, current EOBT+EOBD.
Integration of Gufi handling with legacy systems can be performed in many different ways each having its own vulnerabilities for inconsistency. All Gufi service instantiations via Jumpstart (NMOC, ASA and GCAA) integrate in a totally non-invasive manner with legacy system through a front-end envelope around a legacy system entirely abstracting that legacy system from any awareness of the existence of any Gufi Services or having any notion of the existence of FIXM 3.0.1 based payloads.

As long as flight related information flows in and out through the front-end envelope around a legacy system, a high level of consistency can be maintained:

- Gufi are learned from incoming FIXM 3.0.1 messages.
- A Gufi is generated for outgoing FIXM 3.0.1 messages if there is not yet a Gufi for the flight and if the legacy system is considered to be original source.

However if some flight related information is flowing in from another legacy system using legacy technology (e.g. AFTN) instead of the front-end envelope and if that other legacy system is also exchanging information on the same flight with still more other legacy systems, inconsistencies can appear such as:

- Different Gufi are allocated to the same flight.
- A Gufi has been allocated but is not known.

Unavailability of Gufi

A few questions arise in case a legacy system has no access to a Gufi (e.g. no local Gufi services and a remote Gufi service cannot be reached for some reason) and needs to report an event such as arrival or departure: Can the legacy system publish a FIXM message without Gufi? If so, how is convergence towards an exhaustive and consistent overall view assured?

Multiple Gufi for the same flight

In the course of the rehearsals for the FAA/NextGen-SESAR scenarios, at multiple occasions a situation occurred whereby multiple Gufi were allocated to the same flight. Analysis has revealed root causes for some of these situations but not for all. Examples of documented root causes include no or insufficient cleanup from previous rehearsals, mistakes, anomaly leading to ignorance of Gufi by one system, subsequent self-generation of a Gufi by that system and re-distribution of that information to other systems.

There is no reason why an operational system would not be vulnerable to some of these documented root causes. It would be useful to develop a ATM (Avoid, Transfer, Mitigate) risk approach.

Recommendation #34 [GUFi]

- Explore if functionality to be provided by a Gufi service can be defined in generic manner supporting all legacy systems during a possibly long transition phase towards a global ATM that natively speaks Gufi.
- Provide recommendations on naming, operations and data structures for a Gufi service to maximize reuse across distinct instantiations and allowing for a versioned forward and backward compatible evolution.
- Examine opportunity to globally standardize a minimum contract that every Gufi service shall offer.
- Elaborate on legacy integration models and their pros/cons/risks.
- Elaborate on consistency issues and ways to avoid/mitigate.
- Ask IATA for their lessons learned from their operational use of a concept that is similar to Gufi.
7.4 Flow

7.4.1 Global ATFM
None of the demonstrations has explicitly touched on the subject of Global ATFM. A significant part of all demonstrations implicitly supported the notion of Global ATFM, but we have not made an explicit link with that concept and/or how SWIM could bring value.

Recommendation #35 [Global ATFM]
- Make the value of SWIM in Global ATFM explicitly visible.

7.5 Aeronautical information (AI)

7.5.1 Data inconsistency
Several routes displayed differently in the EU viewers and the US viewers. This could cause confusion and affect flight decisions because of SIGMET & DNOTAM conflicts where one viewer sees the conflict in the route and the other viewer does not.

Digital NOTAMs are not intended to communicate baseline data. An airspace element, such as a Flight Information Region (FIR) or Special Activity Airspace (SAA), may be referenced in a Digital NOTAM but no baseline data defining that element is included. The assumption is that a consumer will have the baseline data available, match the airspace element identifier to the baseline data, and use the baseline data to get information about that element, such as its geographical location. Consumers today will most likely only have the baseline data for their ASP, not for all ASPs.

In addition to lack of international baseline data, we also observed that definitions for the same airspace features can be inconsistent across ANSPs. As an example, we found that SUA W122 in the U.S. (which is made up of two smaller SUAs) is only defined as the two different smaller SUAs by SESAR. When the U.S. activates this SUA via a Digital NOTAM, SESAR is expecting to receive a Digital NOTAM activating the two SUAs instead of the one defined in the U.S. that combines the two airspaces.

Recommendation #36 [Data Inconsistency]
- Synchronize the databases used for waypoints/fixes so that there are global reference points without any confusion.
- First, to conduct international demonstrations, producers will be required to populate the baseline data in a SNAPSHOT section in the AIXM message for NOTAMs.
- Long term, a solution needs to be developed where ASPs can share baseline data.
- Ensure that international baseline data defines airspace features consistently across ASPs.

7.5.2 Data overlap

Different formats
AI data for the USA is available in AIXM 5.1 format from different sources: NASR 56, EAD worldwide minimum data set and NM B2B AIXM Data Sets. For each of the data sources there are textual descriptions that give an indication of its context:

**Examples**

**NM B2B**, extract from NM 20.0.0 - NOP/B2B Reference Manuals - AirspaceServices, Chapter 2.1 Introduction: "The CACD database is the repository for the environment data (a.k.a. airspace data) used in the NM systems to perform Flight Planning and Flow Management. This data includes AIP concepts (such as Routes, Points and Aerodromes), and non-AIP concepts (such as Flows, RAD Restrictions and Traffic Volumes). AIP concepts such as Airspaces may differ slightly from the AIP definition"

**EAD worldwide minimum data set**: "Additionally, the EAD maintains the worldwide (i.e. outside the ECAC area) processed and original NOTAM and some static data, to be used for NOTAM validation and PIB (Pre-flight Information Bulletin) generation."

**NFDC/NASR 56**: "NFDC is responsible for the collection, validation and quality control of aeronautical information that is disseminated to support NAS operations detailing the physical description, geographical position, and operational characteristics and status of all components of the NAS. The NFDC is responsible for providing aeronautical information for operational use by ATCTs, TRACONs, ARTCCs, Air Traffic Control System Command Center, Flight Service Stations, DOD, DHS, private chart producers, airports, pilots, Flight Management Systems, Global Positioning Systems, onboard cockpit displays, moving maps, and data link systems.

**NASR 56** has a notion of "FOREIGN DATA" as explained in this text fragment that is distributed with the data. These subscriber files contain limited information on non-US resources, primarily for context. These should not be considered official source. Refer to current Canadian charts and flight information publications for information within Canadian airspace.

Another example of such data overlap was "AI data for the UAE is available in AIXM 5.1 format from different sources: the publication by GCAA, EAD worldwide minimum data set, and NM B2B AIXM Data Sets". This example is not described here because it is highly similar to the example described below.

Various difficulties emerge when trying to integrate these partially overlapping data sources to create a shared, current and operational situational awareness in a global scenario.

**Note:** All the examples above use AIXM 5.1 as substrate but the essence of the problem does not lie in AIXM 5.1 and would be similar for other exchange formats that could be used for AIS.

**Scope / purpose of usage**

Regarding the scope/purpose of usage, there is no common ontology.

**Example**

EAD worldwide minimum data set uses the notion "Pre-flight Information Bulletin" and NFDC uses the notion of "operational use by pilots". It is not clear if "operational use by pilots" includes "Pre-flight Information Bulletin" or not.

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3 Extract from https://www.ead.eurocontrol.int/eadcms/eadsite/operations/maintenance/responsibility.html

4 Extract from https://nfdc.faa.gov/xwiki/bin/view/NFDC/NFDC+Mission
The scope/purpose of usage is not part of the data or meta-data that is persistently linked with the data. Automated handling requires such presence.

**One authoritative data originator**

An assumption has been made that for each data instance there is only one authoritative entity acting as data originator (creation). It is unclear if this assumption is valid/will remain valid; i.e. will there always (i.e. in the foreseeable future) be only one authoritative entity acting as data originator (creation) for each data instance?

It is not clear to what extent this assumption applies to digital data. Can one such authoritative entity make such data available using multiple means such as both via paper and via (possibly multiple) digital means? If so and if there is a conflict between distinct means, which version prevails at what time?

**Examples of diverging lifecycles**

The NASR 56 AIXM 5.1 publication - assumed to be in the role of data originator - and the EAD worldwide minimum data set AIXM 5.1 publication - assumed to be in the role of data provider - used in all demonstrations both were effective as of March 31st, 2016. It is however unknown to what extent these data sets were aligned.

However the use of the versions effective as of March 31st, 2016 was an artificial constraint linked to the demonstrations: typically and in an operational reality, the EAD worldwide minimum data set AIXM 5.1 publications contain feature instances that are more up to date than the same feature instances provided in the NASR 56 AIXM 5.1 publication. EAD worldwide minimum data set integrates in a quasi constant manner, between USA legacy data publications in the form of data files, additionally USA publications in a form different from data files, whilst the NASR 56 AIXM 5.1 publication is updated only once per 56 days at this time and targeted to be updated every 28 days in future.

Considering this context and a Digital NOTAM issued on April 26th, 2016, it is relevant to know which version of data instances the Digital NOTAM is implicitly or explicitly referencing. If for such Digital NOTAM a lookup of data instance is required, which combinations (e.g. data originator AIXM 5.1 + data originator non-AIXM 5.1, data originator AIXM 5.1 + data provider AIXM 5.1) can be attempted in what order resulting in which grade of reliability (e.g. accuracy and timeliness).

EAD world-wide minimum data set AIXM 5.1 publications contain features for USA that are not in the NASR 56 AIXM 5.1 publication: e.g. Airspace and DesignatedPoint. An Airspace referenced in a Digital NOTAM for USA without inclusion of its geometry, could be looked up in the EAD world-wide minimum data set AIXM 5.1 publication.

These observations lead to a new assumption that for each data instance there can be multiple authoritative entities acting as data provider (publication). But this leads to new questions:

- **If so and if there is a conflict between distinct entities, which version prevails at what time?**
- **If so, is it possible that data is provided at different quality levels (e.g. exhaustiveness, accuracy, timeliness) by distinct authoritative entities?**
- **If so, to what extent can partially overlapping data instances and/or partially overlapping sets of data instances be processed, e.g. combine/merge complementary data elements from distinct data providers to create a superset?**

The level of authoritativeness is not present or is not delimited in a manner that can be processed automatically. All 3 data sets contain data that can be assumed to be created by multiple distinct authoritative entities acting as data originator. For none of the instances of the features there is a...
trace in the data, meta-data or in a separate complementary source to the distinct authoritative entity acting as data originator.

### Recommendations #37 [AI Data Overlap]

- Define an extensible ontology that allows to capture usages of data.
- Define means that allow to the usages to stay attached to the every instantiation of data as well as for a service to advertise the supported usages of the data it accepts and/or data it produces. Such means need to usable for automation. An example that reflects the expression of usage scope/purpose of usage very well, is the manner "key usage" and "extended key usage" are defined for X509v3 certificates:
  - There are intended as well as restrictive usages.
  - There is a standardised list of pre-defined usages.
  - The standardised list of pre-defined usages is extensible both within an overall scope as within a local scope.
  - The usages are part of the data and always travel with the data.
  - The usages are also part of the policy of the service that publishes the data
  - The data can have multiple usages.
- Clarify questions raised above on authoritative entity acting as data originator (creation).
- Clarify questions raised above on multiple authoritative entities acting as data provider (publication).
- Clarify delimitation of authoritative boundaries in order to be usable in an automated manner.

### 7.5.3 Identification and referencing

AIXM 5.1 provides three methods for identification and referencing: **gml:identifier**, **gml:id** and **natural keys**. AI data for the USA is available in AIXM 5.1 format from different sources: NASR 56, EAD worldwide minimum data set and NM B2B AIXM Data Sets.

Any form of lookup, referencing or act of relating between two distinct AIXM 5.1 XML documents requires an unambiguous and shared identification system, which can theoretically only be provided through **gml:identifier** and natural keys.

#### Variations on gml:identifier

NASR56, NM B2B AIXM Data Sets and EAD worldwide minimum data set all use **gml:id**. Interoperability based on **gml:id** within an XML Document is available in all cases.

#### Usability of natural keys

In none of the demonstration a trace was found of any data instance where a natural key expression was used in the form as documented in "Feature Identification and Reference 1.0, Chapter 3.4.2 Using natural keys". There is only limited applicability of this expression. Zero, one or more natural keys could be defined for each feature. Presence of natural keys could be linked with scope/purpose of usage.

Outside the scope of "Feature Identification and Reference 1.0, Chapter 3.4.2 Using natural keys" and without formal standardised register/specification for natural keys, the natural key concept is not usable for interoperability and across data sets nor within data sets because it can only be based on assumptions.
Variations on gml:identifier

The EAD worldwide minimum data set uses gml:identifier. This data set does not share an allocation scheme for gml:identifier with any other data source. An identical real world instance of a feature can have and most probably has a different gml:identifier. There is no interoperability between NM B2B AIXM Data Sets and EAD worldwide minimum data set via gml:identifier. The gml:identifier for EAD worldwide minimum data set are consistent across a version of data: a particular feature instance keeps the same gml:identifier across distinct XML documents of a particular version (e.g. definition in one XML document and referenced in another XML document). The gml:identifier are consistent and interoperable across distinct versions of data: a particular feature instance keeps the same gml:identifier across distinct versions of data: each version of a particular feature instance can be distinguished through "sequenceNumber" and "correctionNumber".

The NM B2B AIXM Data Sets use gml:identifier. These data sets do not share an allocation scheme for gml:identifier. An identical real world instance of a feature can have and most probably has a different gml:identifier. There is no interoperability between NM B2B AIXM Data Sets and EAD worldwide minimum data set via gml:identifier. The gml:identifier for NM B2B AIXM Data Sets are consistent across a version of data: a particular feature instance keeps the same gml:identifier across distinct XML documents of a particular version (e.g. definition in one XML document and referenced in another XML document).

The gml:identifier are consistent but not interoperable across distinct versions of data for NM B2B AIXM Data Sets: the version of a particular feature instance can be distinguished but only through external attributes such as "updatedid".

NASR 56 does not use gml:identifier. There is no interoperability with any other publication of data including other data issued by NASR 56 itself.

Such variations make interoperability more complex.

Composition

A possible way forward could be that the EAD worldwide minimum data set integrates data initially loaded from USA legacy data publications in the form of data files, then mapped from AIXM 4.5 to AIXM 5.1 whereby each AIXM 5.1 feature instance is assigned a gml:identifier that creates consistency across distinct versions of EAD worldwide minimum data set. The EAD worldwide minimum data set additionally integrates, between USA legacy data publications in the form of data files, USA publications in a form different from data files.

However, in that case the EAD worldwide minimum data set creates a notional cross XML document consistency which does not exist at origin through gml:identifier. If such would be the effective process, there is no way to assess the correctness of the assumptions made and the accuracy of the resulting data.

Pragmatic shortcuts used in the SGD

To compensate for the difficulties with identification and referencing following methods have been used in the demonstrations, but they create constraints and they are only workarounds:

- Imposition of the shared use of the identification system and associated data of one data publisher on a group of participants reducing the exhaustiveness of the data
- Making assumptions on natural keys
- Creation of self-standing XML documents reducing but not eliminating the need for lookup of complementary information
Example

A Digital NOTAM for a Runway(RunwayDirection) closure is issued using a TEMPDELTAL. The Digital NOTAM does not contain an instance of the RunwayElement feature, hence there is no way to associate a RunwayElement via the natural key mechanism as described in "Feature Identification and Reference 1.0, Chapter 3.4.2 Using natural keys". Only via gml:identifier complementary information on the Runway and RunwayDirection can be found in the imposed shared use of the data from one particular data publisher.

To be able to graphically represent the impacted area on a map, the RunwayElement is needed but this information is not present in the data from the one particular data publisher that is imposed. A lookup of the RunwayElement associated to the Runway is either based on an assumed natural key usable in another source or requires another source with complementary information to synchronise its gml:identifier with those of the one particular data publisher that is imposed.

Recommendation #38 [AI Identification and Referencing]

- Clarify the “natural key” concept beyond “Feature Identification and Reference 1.0, Chapter 3.4.2 Using natural keys”.
- Clarify variations of gml:identifier
- Clarify compositions
- Clarify identification and referencing in Digital NOTAM Event Specification and in the AIXM Temporality Concept

7.5.4 Digital future: the new ICAO Annex 15

A new ICAO Annex 15 (Fifteenth Edition) is in preparation. The draft version provides a number of statements/chapters that have high relevance for all AI related topics. From this draft text, assumptions such as following could be derived: "It will be the responsibility of the AIS of each State to ensure that the digital static data (BASELINE) and the Digital NOTAM (TEMPDELTAL) are consistent, including the use of the same gml:identifier, coherent sequenceNumber, etc."

This draft text impacts also above topics "6.5.1 Data overlap" and "6.5.2 Identification and referencing" but the extent (proliferation) is not clear.

Example

A flight between USA and Europe exists in both FAA systems and Eurocontrol systems. The visibility on and during various stages of the flight from FAA systems is not necessarily the same as the one from the Eurocontrol systems as they for instance do not use the same AIS.

Questions that need to be answered: To what extent can a regional flight planning system deviate from using the Aeronautical data set as planned in the new ICAO Annex 15? To what extent will the new ICAO Annex 15 help improve the issue of "Inconsistent flight information"?

Recommendation #39 [AI Digital Future]

- Clarify the targeted "digital future" of AIS and distribution of responsibilities,
- Clarify transition phases towards the targeted "digital future" as such phases could take a long time and/or one such phase could even become a terminal state
8  Business view

**Emirates Airlines:** 'We need more of those live SWIM Global Demonstration Flights’ in order to show/prove what even today is already possible to gain benefits – and to motivate all stakeholders to continue. There is value and efficiency already today!

**Network Manager (EUROCONTROL):** ‘The showcase was just a small window on what happens in operations between NM and around 200 organisations worldwide. SWIM is operational and is allowing these organisations to improve their business effectiveness and is creating new business opportunities. The simplicity of the technologies used allows to quickly develop interoperability layers on top of the existing systems, opening them and leveraging their functions. NM and its users have now a much higher level of process automation, enabled by the automatic data exchange. Examples are the 100% pass rate of flight plans filed via B2B, demonstrated in the showcase by RocketRoute.’

8.1  Stakeholder participation

There has been significant and very active participation in the demonstrations from the side of the operational Civil Aviation Authorities.

There has been significant and very active participation in the demonstrations from the side of the operational Industry.

Only two operational Airlines have actively participated and one Airline has shown very significant enthusiasm on SWIM and its further evolution.

From the operational Airport side there has been minimal active participation.

SWIM is targeted to bring value to all of ANSPs, Airlines and Airports and yet Airlines and Airports were quasi absent. Some possible reasons on the airline side:

- Intense competition drives the airlines to minimize cost. Many airlines have therefore cut down or eliminated operational development. This is especially valid when the benefits will materialize within all airlines and not just their own.
- Airlines are reluctant to participate in development/projects where the benefits are not nearer term (1-2 years). Airlines policies exist where anything that had a return on investment longer than 18 months should not be engaged in.
- Many airlines have policies to engage only in core business and rely on others to advance technical/operational progress. This is clearly a result of deregulation. Before deregulation many larger airlines were driving technical/operational progress actively. As a consequence many airlines are expected to have a lower degree of knowledge regarding systems and standards amongst decision makers and operational staff.

**Recommendation #40 [Stakeholder Participation]**

- Analyse and identify the reasons of low active participation of Airlines and Airports
- Analyse and identify the reasons of the enthusiasm of SGD participating airlines to understand the value that SWIM brings to Airlines
- Re-assess if the current direction of SWIM really covers the most important operational needs of Airports and really brings value to the Airports

8.2  Value chain

The ATM world does not stand on itself but is part of a larger value chain and with which interoperability à la SWIM can be expected to represent major value.
Other major stakeholders such as IATA, ACI and OTA (not exhaustive) have at least partially similar concepts as SWIM (AIDX, ACRIS, OpenTravel Schema), can be considered as Partners with direct interest in SWIM, i.e. directly neighbouring. The mutual integration with each other’s automated systems could be expected to bring mutual benefits and value.

None of such integration has been highlighted and/or demonstrated.

Interoperability with another major Stakeholder with direct interest in the ATM has not been highlighted except through a DNOTAM: the military.

**Recommendation #41 [Value Chain]**

- Elaborate on operational needs, benefits and costs for integration with other SWIM worlds such as IATA, ACI and OTA.
- Define/align standardisation for information sharing between SWIM and other directly neighbouring SWIM-like worlds.

### 8.3 Legacy integration

A subset of legacy systems of a number of Stakeholders has been integrated in the demonstrations. These integrations were successful and they dealt with several and distinct domains. It has demonstrated that a step-wise approach to the integration and joining of the SWIM is possible.

However, this integration was not clearly highlighted during the demonstrations. Also, we may seem to be missing examples of business case blueprints of "how to proceed from here to there".

**Recommendation #42 [Legacy Integration]**

- Elaborate on operational needs, and business case blueprints of how they can moved to/integrated with the SWIM world in a step wise manner

### 8.4 Automation

The demonstrations were focused on the visualisation of information sharing and how in a particular a human stakeholder could take profit from the available information.

SWIM also creates a huge opportunity to eliminate in many ways human intervention and/or even systems. This has hardly been highlighted. For example: what about fully automated boundary coordination, what about much more information sharing with the FMS?

Linked with the value chain above, it can be expected that information shared at quasi speed of light, can trigger relevant processes much earlier and allow significantly improved planning in an automated way. None of such has been demonstrated. Also, how far can we go with such automation and in what timespan from a societal perspective?

The potential in automation based on standardized and digitized data may be especially true within the ATM domain but is probably valid also for air operators.

**Recommendation #43 [Automation]**

- Elaborate on operational needs and processes and how automation through SWIM can bring benefits at a global/interregional scope
9 Next steps

The exploration of the Global ATM concept with the global interoperability demonstrations so far has yielded platforms, experience, insights and lessons learned.

Using these achievements and when feedback is ingested/digested, a new series of global interoperability demonstrations would allow to go more in depth and further, and advance more towards an operational context.

A number of full scale shadow systems of real operations have been used in the demonstrations but not systematically and not by every participant. In particular such new series of global interoperability demonstrations should take place in real environments to increase their operational value.

**Recommendation #44 [Global Interoperability Demonstrations]**

- Use the momentum and plan more global interoperability demonstrations
- Use future global interoperability demonstrations to validate new operational information exchanges, including FF-ICE/1
## 10 ICAO ASBU coverage

The reference to determine the coverage is the ICAO document “The Aviation System Block Upgrades” [ref 9].

<table>
<thead>
<tr>
<th>B0-FICE</th>
<th>Demonstrated to some extent through some mapping of OLDI/AICD elements onto FIXM (the handover of the LIMC-KATL flight).</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1-FICE</td>
<td>Basis and services have been demonstrated partially through use of FIXM and XML, use of FlightPlanValidation function NMOC by USA FOC before actual filing, use of constraints sharing because effectively constrained due to use of PREOPS and sharing of weather and AI constraints as well, use of GUFI, publication of flight information via Publish/Subscribe. Other elements of B1-FICE could not be demonstrated because of:</td>
</tr>
<tr>
<td></td>
<td>- unclarities in Doc 9965</td>
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<tr>
<td></td>
<td>- missing components:</td>
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<tr>
<td></td>
<td>- mapping of Doc 9965 -&gt; FF-ICE Implementation Guide</td>
</tr>
<tr>
<td></td>
<td>- mapping of FF-ICE Implementation Guide -&gt; FIXM Implementation Guide</td>
</tr>
<tr>
<td></td>
<td>- unclarities in FIXM 3.0.1</td>
</tr>
<tr>
<td></td>
<td>- systems not ready</td>
</tr>
<tr>
<td>B0-DATM</td>
<td>The scope is entirely covered.</td>
</tr>
<tr>
<td>B1-DATM</td>
<td>A large part of the scope is covered including sharing of integrated information using IWXXM, FIXM and AIXM.</td>
</tr>
<tr>
<td>B1-SWIM</td>
<td>The scope is entirely covered</td>
</tr>
<tr>
<td>B2-SWIM</td>
<td>Some aspects have been demonstrated such as the FMS sharing its current intended 4D trajectory with the Ground systems as well as FMS picking up a variety of information from Ground systems.</td>
</tr>
<tr>
<td>B0-AMET</td>
<td>SIGMET/OPMET element is covered to a large extent, not the others</td>
</tr>
<tr>
<td>B1-AMET</td>
<td>The aspect of using IWXXM is covered</td>
</tr>
</tbody>
</table>
11 References


[3] ICAO ATMRPP’s draft provisions on FF-ICE/1.


