1 General

1.1 Mandate
The NextGen - SESAR Data Model Coordination Group (NSDMCG) has a task to support and ensure the convergence of definitions which are common to the SESAR AIRM and the NextGen OV-7. In order to support the interoperability goals of the SESAR and NextGen programmes, the following objectives are pursued:

• Facilitate semantic information/data interoperability through common information/data definitions.
• Facilitate sharing interoperable information/data through common structures and rules (e.g. for how to map a model within an implementation context).
• Foster unambiguous understanding through common agreements and standards (e.g. codelists).

As a part of the NSDMCG proceedings two white papers were previously written:

• “ICAO Air Traffic Management Information Reference Model (AIRM) considerations” [Ref 7].
• “ICAO Air Traffic Management Information Reference Model (AIRM) governance considerations” [Ref 8].

Following NSDMCG discussions and further stakeholder consultations, the group decided to continue developing the ICAO AIRM concept by placing it within the wider context of an ICAO Semantic Framework and by providing a high level description of the components of the ICAO AIRM.

This white paper titled “ICAO AIRM and Semantic Framework Considerations” is the result of this work.

Building on the lessons learned within SESAR and NextGen, the proposed ICAO Semantic Framework (ISF) and the components it contains serve as reference and guidelines for organizations implementing SWIM based interoperable information exchanges.

1.2 Scope
This paper contains draft ICAO AIRM and Semantic Framework considerations produced by SESAR/NextGen coordination under the umbrella of the US/EU CP2.1 coordination. The paper introduces the ICAO Semantic Framework as the container for the ICAO AIRM components.

This paper does not:
• Discuss the governance aspects of the ICAO AIRM and ICAO Semantic Framework. It is expected that the governance of the ICAO AIRM will be the subject of further work which builds upon earlier considerations [Ref 8].
• Discuss the compliance and alignment mechanisms that will be necessary to preserve semantic interoperability across stakeholder communities. This will ensure that models created in different stakeholder communities will retain a consistent meaning, thus fostering increased interoperability levels.
• Elaborate on the current well-established ATM Exchange Models for which the ICAO AIRM will become the future reference. It should be clear that both ICAO AIRM and ATM Exchange Models complement each other.

1.3 Audience
The anticipated readership for this document includes:

• The NSDMCG.
• The leadership of Coordination Plan 2.1 (CP2.1), CP3.1, CP3.2, and NextGen/SESAR leadership.
• Federal Aviation Administration (FAA) / EUROCONTROL.
• Members of the ICAO Information Management Panel (IMP) and relevant sub-groups.

1.4 Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>AIRM</td>
<td>ATM Information Reference Model</td>
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<td>ATM</td>
<td>Air Traffic Management</td>
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<td>ATMRPP</td>
<td>Air Traffic Management Requirements and Performance Panel</td>
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<td>CLDM</td>
<td>Consolidated Logical Data Model</td>
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<td>DoD</td>
<td>Department of Defense</td>
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<tr>
<td>CP</td>
<td>Coordination Plan</td>
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<td>EUROCONTROL</td>
<td>European Organisation for the Safety of Air Navigation</td>
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<tr>
<td>Exchange Model</td>
<td>Current ATM related Exchange Models such as AIXM, WXXM, FIXM, ASTERIX, AIDX,...</td>
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<td>FAA</td>
<td>Federal Aviation Administration</td>
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<td>GIF</td>
<td>Global Interoperability Framework</td>
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<td>ICAO</td>
<td>International Civil Aviation Organisation</td>
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<tr>
<td>ICAO AIRM</td>
<td>The AIRM as considered in the global interoperability discussion at the ICAO level</td>
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<td>IER</td>
<td>Information Exchange Requirement</td>
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<td>IGIF</td>
<td>ICAO Global Interoperability Framework</td>
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<td>ISF</td>
<td>ICAO Semantic Framework</td>
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<td>ISO</td>
<td>International Organisation for Standardisation</td>
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<td>ISRM</td>
<td>Information Service Reference Model</td>
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<td>NAS</td>
<td>National Airspace System</td>
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<td>NCOIC</td>
<td>Network Centric Operations Industry Consortium</td>
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<td>NextGen</td>
<td>Next Generation Air Transportation System</td>
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<td>NextGen OV-7</td>
<td>Next Generation Air Transportation System Operational View 7 Logical Data Model</td>
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<td>NSDMCG</td>
<td>NextGen - SESAR Data Model Coordination Group</td>
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<td>OV</td>
<td>Operational Information Model View</td>
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<td>SESAR</td>
<td>Single European Sky ATM Research</td>
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<td>SESAR AIRM-CLDM</td>
<td>Single European Sky ATM Research AIRM Consolidated Logical Data Model</td>
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<td>SOA</td>
<td>Service Oriented Architecture</td>
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<td>SWIM</td>
<td>System Wide Information Management</td>
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1.5 References

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<thead>
<tr>
<th>Reference</th>
<th>Title and Details</th>
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<tbody>
<tr>
<td>[Ref 1] ICAO ATMRPP, 2014</td>
<td>SWIM Concept</td>
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<tr>
<td>[Ref 3] ICAO Doc 9854, 2005</td>
<td>Global ATM operational concept</td>
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<td>[Ref 4] NCOIC, 2010</td>
<td>NCOIC Interoperability Framework (NIF)</td>
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<td>[Ref 5] EU, 2011</td>
<td>European Interoperability Framework (EIF)</td>
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<tr>
<td>[Ref 6] NIEM, 2007</td>
<td>Introduction to the National Information Exchange Model (NIEM)</td>
</tr>
<tr>
<td>[Ref 8] CP2.1-NSDMCG, 2013</td>
<td>ICAO Air Traffic Management Information Reference Model (AIRM) governance considerations</td>
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1.6 Document Organisation

This document contains the following sections:

- General.
- Semantic Interoperability.
- ICAO Semantic Framework (ISF).
- Recommendations.
- Summary and future steps.

1.7 Key assumptions

It is assumed that the reader is familiar with the following NSDMCG papers:

- “ICAO Air Traffic Management Information Reference Model (AIRM) considerations” [Ref 7].
- “ICAO Air Traffic Management Information Reference Model (AIRM) governance considerations” [Ref 8].

It is assumed that the reader is familiar with the following concepts:

- Interoperability - The general concept of interoperability and the different concerns that need to be addressed [Ref 1].
- SOA - The general concept and value of SOA is known [Ref 7].

2 Semantic Interoperability

Semantic interoperability is a recognized [Ref 1, Ref 4, Ref 5, Ref 6] specific concern within the overall interoperability problem space. Semantic interoperability ensures that:

- The meaning of exchanged information is unambiguously understood by all interoperating parties, including parties in different ICAO regions.
- The meaning of exchanged information is not lost or altered as it travels through the end-to-end data chain (from the point of origin to the point of destination).

Semantic interoperability enables services and systems to combine and process information received from multiple authorized sources. For example:
• When a user receives information about a runway from different authorized providers he/she is able to seamlessly process the information and, depending on the application context, add and combine information from other authorized information sources.

• When an airspace user is directed to arrive on a named runway, he/she will be assured that the runway reference received can be unambiguously resolved to the relevant geospatial information, and linked to the meteorological information relevant to this runway at the planned arrival time.

Note: within the U.S./FAA context the term “authorized source” is referred to as “authoritative source.” U.S./FAA defines: “Authoritative source is the designated repository for authoritative data or information provided by the steward. Steward is the designated organization that originates and is accountable for quality and timeliness of data and information.”

3 ICAO Semantic Framework (ISF)

3.1 Background

3.1.1 ICAO

One of the roles of the International Civil Aviation Organization (ICAO) is the establishment of communication and information standards. For example, “Procedures for Air Navigation Services - Air Traffic Management (Doc 4444)” [Ref 2], standardizes both the phraseology used by pilots and controllers, and the data exchanged to communicate flight intent and flight reports.

This role is essential to realizing the ambition of the “Global ATM operational concept” (Doc 9854) [Ref 3] where SWIM is introduced by stating that “System-wide information management, or simply information management, aims at integrating the ATM network in the information sense, not just in the system sense. This fundamental change of paradigm forms the basis for the migration from the one-to-one message exchange concept of the past to the many-to-many information distribution model of the future, that is, many geographically dispersed sources collaboratively updating the same piece of information, with many geographically dispersed destinations needing to maintain situational awareness with regard to changes in that piece of information.”

This “fundamental change” clearly requires that ATM has an agreed and shared understanding of the definition of “the same piece of information” which can be relied upon by all ATM stakeholders. Such definitions must also be preserved across domain, community of interest and international boundaries to ensure that information from different authorized sources can be seamlessly integrated, e.g., that information from flight reports can be seamlessly integrated with aeronautical or meteorological information (see Figure 1).

![Figure 1: example of seamless integration of information](image-url)
Therefore, an ATM-wide approach to agreeing information definitions (including consolidation of the current definitions) using a common strategy is required. The proposed ICAO Semantic Framework serves this purpose.

3.1.2 Other Interoperability Frameworks

Obviously, the need for interoperability is not unique to ATM. Indeed, the need for, and benefit of, an interoperability framework has been identified in other businesses already. This has resulted in frameworks such as the Network Centric Operations Industry Consortium (NCOIC) Interoperability Framework (NIF), the European Interoperability Framework (EIF) and the National Information Exchange Model (NIEM).

These frameworks re-enforce the importance of separating the semantic concern. The semantic concern is recognized as being only one part of the complex problem of interoperability standardization, governance and management within an interconnected, collaborative, multi-stakeholder and multi-community environment. By separating this concern, it becomes focused and manageable which, in turn, fosters consensus building.

To illustrate, the Network Centric Operations Industry Consortium (NCOIC) Interoperability Framework (NIF) [Ref 4] developed to serve the needs of the U.S. DoD states: “The Semantic Interoperability Framework (SIF) examines information objects, information exchange requirements (IERs) and information exchange models to develop guidelines for seamless sharing of information throughout and between enterprises.” The identification of this concern stems from the basic network centric principle which is “to be explicit”. Indeed, as indicated by the NIF, “Many network centric problems come from implicit assumptions that are not documented or shared between networked parties.” This frequently occurs at the level of syntactic and semantic information.

The European Interoperability Framework (EIF) [Ref 5] developed to support the networking of the European national agencies under the umbrella of shared European Union provisions, states about the semantic framework, as one of its specialised frameworks: “The semantic level can take the form of reference taxonomies, schemes, code lists, data dictionaries, sector-based libraries, etc.” The semantic framework of the EIF is one of the specialised frameworks it contains. The goal is to ensure the “Precise meaning of exchanged information which is preserved and understood by all parties.”

Continuing citations, the National Information Exchange Model (NIEM) developed by the U.S. Department of Justice, Department of Homeland Security, and Department of Health and Human Services [Ref 6] states that it is “designed to develop, disseminate, and support enterprise-wide information sharing standards and processes across the whole of the justice, public safety, emergency and disaster management, intelligence, and homeland security enterprise at all levels and across all branches of government.” Furthermore, it “connects communities of people who share a common need to exchange information to advance their missions.” At the heart of this are, “data components within an information exchange that are universally shared and understood among all (or almost all) domains are identified as universal components (e.g., person, address, and organization). To become a universal component, consensus by all domains is needed on the semantics and structure of the component. The set of NIEM universal components is stable (once established) and relatively small.” Finally it concludes that, “NIEM components are not merely a set of stand-alone components to build messages; together they form a cohesive data model that attempts to provide consistent semantics and structure. To effectively exchange information, there must be a common semantic understanding of data among participating agencies, and the data must be formatted in a semantically consistent manner.” Consequently, NIEM can be interpreted as a key component of an inter-agency interoperability framework at the federal U.S. level.
Taking the need for semantic interoperability and the lessons from other interoperability frameworks into account, this paper further discusses the ICAO Semantic Framework (ISF).

3.2 ICAO Semantic Framework

3.3 Definition

The ICAO Semantic Framework (ISF) is the minimum set of common elements (e.g. data architecture structure, metadata, definitions, concepts, principles, policies, guidelines, recommendations, standards, specifications and practices) that define the agreed meaning of ATM information. One ISF key component is the ICAO AIRM, as introduced by the ICAO Global Air Navigation Plan (GANP), following the 12th Air Navigation Conference (ANC).

The ISF aims to ensure that terms and definitions are well understood and managed, and appropriate for ATM, more specifically in the context of SWIM based interoperable information exchange.

The ISF recognises that information is a key business asset, and ensures that it is governed and managed in a way that is appropriate for SWIM. For instance, it recognises that the definition of information should be independent of any specific platform, solution or exchange approach. This is particularly true in the air traffic business where specific constraints exist within the different segments of communications (ground/ground, air/ground, air). As a consequence there is no single technical implementation of information sharing that fits all needs of all ATM stakeholders.

3.3.1 Need and benefits

As introduced before, ISF is a key consideration in the context of SWIM and the Service Oriented Architecture (SOA) approach to information exchange. The principles of SOA include the loose-coupling of services and the ability to combine services together whilst preventing loss and uncontrolled altering of information meaning. In the context of SWIM, the ISF provides a set of components that enable the management of the semantic layer.

Furthermore, when expressing new information exchange requirements, identifying and designing services, and finally implementing services and SWIM enabled applications; the use of the ISF enables ATM stakeholders to:

- Refer to a common vocabulary.
- Agree on the common understanding of information and the preservation of understanding during implementation and actual information exchange.

From a standardisation point of view, the use of the ISF enables vertical alignment between the overall ATM enterprise and its specific ATM communities, and horizontal alignment between the ATM communities and stakeholders themselves.

As such, the ISF works as a semantic “bridge” between different processes/contexts, which is fundamental to ensuring that information can be reused outside of its original context, e.g. to link with related upstream or downstream activities, and possibly unlock its full potential.

In summary the key benefits of the ISF are:

- Semantic interoperability within and between communities.
- Facilitation of solution specific Exchange Models and services (e.g. global and inter-regional SWIM developments).
• Governance and management of semantic interoperability.

3.3.2 Risks mitigated by ISF

If semantic interoperability is not achieved, the following would result:

• Safety hazards due to semantic misinterpretation between providers and consumers.
• Increased cost of ad hoc semantic alignment work and rework among communities.
• Failure to leverage the economies of standardisation (e.g. longer term to market).

3.4 ISF structure and components including ICAO AIRM

Within the context of SESAR AIRM / NextGen OV-7 harmonisation the following potential structure is identified as depicted in Figure 2 below. Each component is described in the paragraphs that follow the figure.

![Diagram of ICAO Semantic Framework components]

Figure 2, ICAO Semantic Framework components

3.4.1 ICAO AIRM

The ICAO AIRM is a key component of the ISF. It contains formalised reference information and data representations which are expressed using UML. The ICAO AIRM includes a Glossary which provides a textual representation of the terms and definitions used in the ICAO AIRM. The Glossary includes additional descriptive data (metadata) such as the reference to the source. It is an automatically generated export of the ICAO AIRM.

3.4.2 Rulebook

The Rulebook component contains a set of applicable conventions. The Rulebook provides principles, rules and recommendations in order to facilitate the development and maintenance of the ICAO AIRM. The principles, rules and recommendations are intended to be used for modelling, consolidation, validation and verification, compliance, and quality check purposes.
Possible examples:
- Compliance rules.
- Naming conventions.
- Change Request mechanism.
- Extension mechanisms.

3.4.3 Standards Baseline
The Standards Baseline contains a formal representation of the content of those normative foundation standards that are used by the ICAO Semantic Framework.

The Standards Baseline is provided as an explicit subset of the Standard Catalog. The formal representation is either an import of the complete standard or a sub-set of its content. Since these standards are included within the ISF they are managed at that level as a formally controlled copy. As a consequence, versioning remains independent from the source standard versioning.

3.4.4 Standards Catalog
The Standards Catalog component is the list of referenced standards described by metadata. An example of associated metadata is the owner or source of the standard. The Standards Catalog contains normative documents from ICAO or other recognized organisations such as ISO.

3.4.5 Manual
The Manual component contains all necessary introductory and guidance material to fully understand and use the ISF. As is the case for international standards, this includes a Primer document.

3.5 Content of the ICAO AIRM

3.5.1 ICAO AIRM Subject Fields
The ICAO AIRM describes information related to flights and the supporting ATM specific operations and infrastructure. The ICAO AIRM is divided into several parts, each corresponding to a particular subject field. A subject field is a field of specific knowledge. These are depicted in Figure 3 below. Within the context of this paper the content of the subject fields is not further detailed.

Figure 3, ICAO AIRM subject fields
Note: the U.S./FAA/NAS OV-7 refers to the term Subject Field as Subject Area.

The Flight subject field describes concepts about a specific flight and its trajectory. It is defined as an entity using a definition extracted from ICAO Annex 13. However, as a flight is enabled by ATM operations and uses infrastructure, it is linked to the relevant entities from related subject fields. For example, the information relevant to the Flight subject field would typically include the information concept of aerodrome whose Annex 15 definition is included in the BaseInfrastructure subject field, and potentially also includes a meteorological report that is defined by Annex 3 and defined as part of the Meteorology subject field.

The AirTrafficOperations, Surveillance, Meteorology and Environment subject fields describe concepts about the operations that are necessary for safe, efficient and environmentally friendly flights. For example, the ICAO METAR is captured in the Meteorology subject field.

The BaseInfrastructure (where for example the “aerodrome” concept is found), AirspaceInfrastructure and Aircraft subject fields describe concepts about the infrastructure of ATM. The infrastructure exists even if no operations are actually conducted.

The StakeholderAndActivities, and the Common subject fields are of a transversal nature. For example information on stakeholders and the activities they perform. The Common subject field contains, geometries, times, code lists, and value domains (i.e. constraints on data also defined by ISO-19103 as the “Set of accepted values”). Consequently all of the concepts of the other subject fields will have to share the same underlying notion of what a “geographical point” is in order to be capable of being merged together into meaningful information exchanges.

3.5.2 Defining the ICAO AIRM Content

There is a need to define the content of the subject fields. The subject fields should focus on a “common core”. This means focusing on the minimum requirement from a global perspective. This does not necessarily exclude items that are of purely regional or national scope when agreed upon at the global level.

It is obvious to the NSDMCG that, when harmonizing the SESAR AIRM and NextGen OV-7, it does not fully represent the global ATM community. However, the SESAR AIRM / NextGen OV-7 harmonisation work is used to provide a rationale as to the particular elements that should be “promoted” to the “common core”. This is based on the assumption that both models together represent in terms of content (horizontal scope) and level of abstraction (vertical scope) a sufficient baseline from where to start working towards a globally acceptable subset. Determination of applicability at the global level is required to define the content of the subset. [Ref 7, Ref 8]

When harmonizing the SESAR AIRM with NextGen OV-7, and knowing that the result of this harmonisation is a subset of the original model scopes, it is possible to state that three parts emerge (Figure 4):

- The SESAR AIRM specific part.
- The NextGen OV-7 specific part.
- The SESAR AIRM and NextGen OV-7 harmonised part (the actual result of the harmonisation).
When reasoning about the scope of the “common core” that contains candidate content for the ICAO AIRM, two fundamental options are possible:

- The common core is a subset of the “union” (union=harmonised + specific) of all semantic content stemming from SESAR AIRM and NextGen OV-7.
- The common core is a subset of the “intersection” (intersection=harmonised only) of all the harmonised semantic content stemming from SESAR AIRM and NextGen OV-7.

Figure 5, represents both “union” and “intersection” options. However, additional considerations quickly emerge when looking closer into these basic options:

- “Common core” as a “union”: this represents an “all inclusive way” towards global semantic interoperability; however this also promotes all regional specificities to the global level. Applicability at the global level of regional specificities is in principle less recommendable.

*Note: in some cases regional differences are actually put into the harmonised part of the models as harmonisation does not always imply making a choice of one option over another. A typical example is units of measure. Although different in some regions they are managed as part of the “common core” to ensure the meaning is understood by all and this meaning is put in a “known and managed” state.*

- “Common core” as an “intersection”: the “intersection” should follow the same reasoning as applied to the union approach, i.e. not all elements, even if harmonised, are de facto promoted to the global level, thus it is a subset of the harmonised part which is promoted to the ICAO level.

Between the two basic options cited above more is to be said about the specific parts. Indeed, the specific parts which are technically not harmonised between SESAR AIRM and NextGen OV-7 because:

- Only represented in one model, may be proposed and further considered as candidate inputs.
- Fully outside the scope of both models may be proposed and further considered as candidate inputs (e.g. this could be an extension within a given context).
- Represented in both models, but subject to harmonisation resolution and therefore less recommendable candidates. Following harmonisation this may lead to new candidate inputs at a later stage.

As a consequence of the above considerations, the most probable approach is to consider the “common core” logic as being a partial “intersection +”, as shown in Figure 5 hereafter.
3.6 Where to start – plan
Working towards populating an initial version of the ICAO AIRM and starting with those parts needed by all, it is proposed to work on the BaselineInfrastructure, AirspaceInfrastructure and Common subject fields including the UML representation of current ICAO Terms and their relationships, and start populating the components of the ICAO Semantic Framework accordingly. As a consequence, the idea is to start with ICAO Annex 15, and Annex 14 related content in combination with a full set of ICAO Terms.

3.7 Technical framework considerations
It is obvious that ISF agreements only partly cover the interoperability issues. Typically, there may be a need to promote to the ICAO level elements of a more technical nature. These may be more closely related to the physical space. For instance, it may provide added value to standardise namespaces, unique identifiers, stereotypes in support of UML/XML conversion automation, etc. It is clear though that careful consideration shall be made on their status as being normative or informative, and whether required at the global level or not. It is not the intent of this paper to dig deeper into this aspect.

4 Recommendations
Taking into account the content of this paper it is recommended to consider establishing the ICAO Semantic Framework and start developing the BaselineInfrastructure, AirspaceInfrastructure and Common subject fields including the UML representation of current ICAO Terms, and start populating the components of the ICAO Semantic Framework accordingly.

This will lead to a candidate release of the ICAO AIRM which can be used in proof-of-concept activities. Once agreed, the candidate release will be incremented to a first version of the ICAO AIRM.
5 Summary and future steps

This paper introduced the notion of an ICAO Semantic Framework (ISF) as one of the specialised frameworks of the future ICAO Global Interoperability Framework (IGIF). The paper proposed considerations based on EU/US CP2.1 coordination work about the structure and content of the ISF. The paper also proposes to start with a candidate release of the ICAO AIRM, as a first step leading towards the establishment of an ICAO AIRM.

The ICAO AIRM is based upon a seamless approach which is ATM wide and integrates all constituting domains. Yet the ICAO AIRM does not replace any domain and solution space Exchange Model/Schema.

The ICAO AIRM fosters semantic interoperability at the “systems-of-systems” level when defining services. When implementing services the ICAO AIRM enables the semantic interoperability of Exchange Models/Schemas.

6 Contributors

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<td>Michael Burski</td>
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<td>Barbara L Cordell</td>
<td>FAA</td>
</tr>
<tr>
<td>Allen Perper</td>
<td>BAH/FAA</td>
</tr>
<tr>
<td>Katrina Wilson</td>
<td>FAA</td>
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<tr>
<td>Diana Takata</td>
<td>FAA</td>
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<tr>
<td>Sam Van der Stricht</td>
<td>Eurocontrol</td>
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<td>Scott Wilson</td>
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<td>Robert Suzić</td>
<td>Eurocontrol</td>
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<tr>
<td>Stefan Keller</td>
<td>DFS</td>
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<td>Joe Gorman</td>
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