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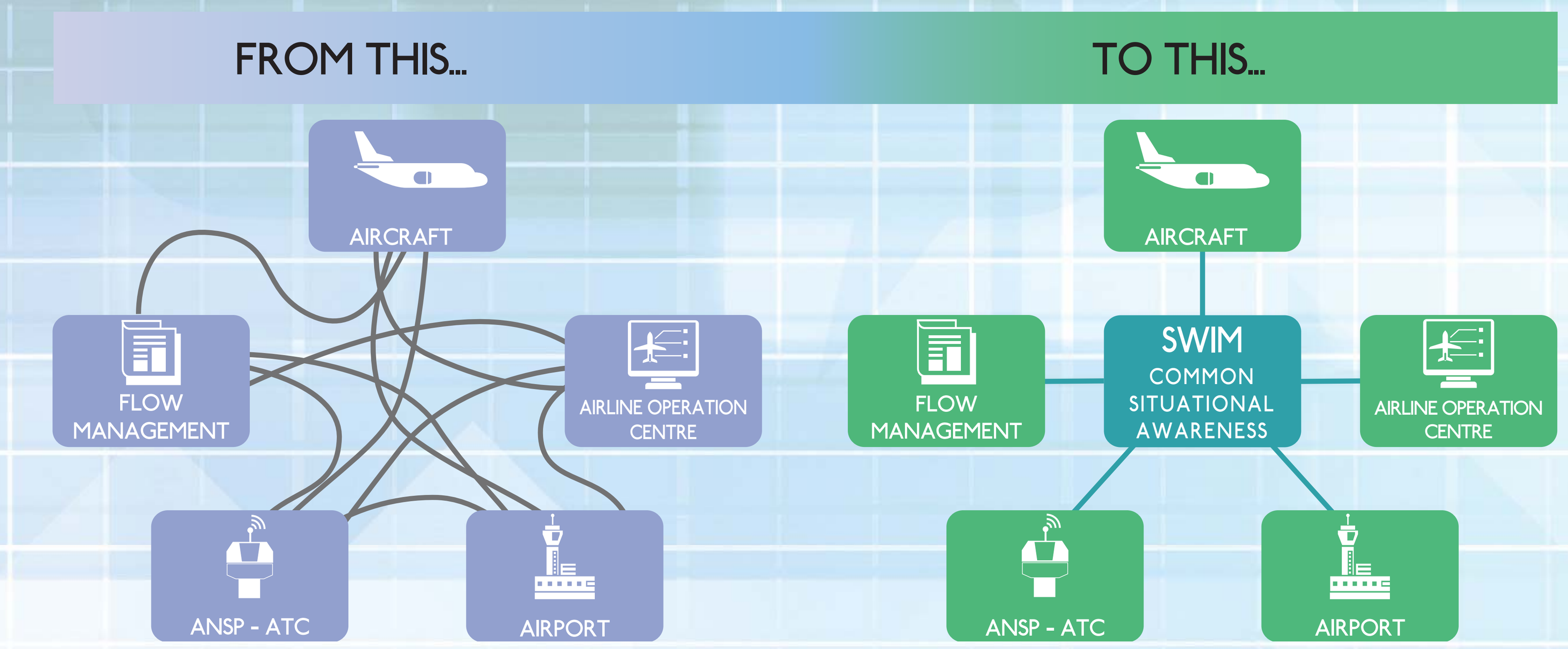
ACHIEVING THE BENEFITS OF SWIM BY MAKING SMART USE OF SEMANTIC TECHNOLOGIES

What is BEST?

BEST is a SESAR Exploratory Research project providing on a new way of information handling. BEST will determine how semantic technologies can be used effectively to maximise the benefits of adopting System Wide Information Management (SWIM), one of the major results of SESAR.

SWIM offers an "information sharing" approach to ATM information management and its adoption offers advantages for better situational awareness and information management. SWIM means in principle that all aviation related information will be available for those who need it from the source that is best placed to provide it. This represents a real shift from today's bilateral aviation ICT environment to a real network based approach, as illustrated in the figure below.



BEST will experiment with and evaluate the use of semantic technologies in several realistic ATM use cases. Semantic technologies are advanced tools and techniques enabling flexible information management, including information extraction and integration from multiple sources (more details provided in section 4 below). The aim is to support the new paradigm for ATM information management envisioned by SWIM. The project will use practical experience gained in the project to produce guidelines for practitioners about how these technologies can be used in innovative yet scalable ways in order to support the mission of SWIM.

BEST envisages use of multiple modular ontologies. Ontologies are an essential component in semantic technologies, providing a way to define information and relationships in a formal, "mathematical" way (more details provided in section 4 below). Concepts expressed using ontologies represent metadata describing data sought and made available according to the SWIM approach. The metadata will then be used by other semantic applications developed in the project to support identification, aggregation and distribution of relevant ATM information.

We believe that this will maximise flexibility and applicability to specific application scenarios, but it has to be performed within a framework where compliance with the wider requirements of SWIM and the SESAR AIRM (details on this below) can be assured. This involves both technical compliance testing and governance aspects.

While BEST is primarily a research-oriented project, it is also designed to ensure relevance to and suitability for ATM operations, through project activities and the involvement of a Reference Group of key stakeholders.

Expected Concrete Results

R1 Prototype SWIM-enabled applications. R1 is a proof-of-concept prototype to demonstrate the potential of the semantic-based approach used in BEST. It is built using semantic technologies and demonstrated in 2 pilot demonstrators

R2 Experimental ontologies formalizing aspects of ATM data / metadata. The ontologies are used for describing the content in semantic data containers / decentralized knowledge bases.

R3 Techniques for ontology-based data description and discovery in a decentralized SWIM knowledge base. R3 comprises a method for the semantic description of data products providing requirements on how to formalize ontologies, and techniques for discovering most relevant data products for a given information need.

R4 AIRM compliance validator is a prototype software application that will identify correspondences among an AIRM Ontology developed as a representation of the AIRM Information Models and the ontology modules developed in BEST.

R5 Strategies for data distribution in a SWIM Environment. R5 comprises an ontology-based language for describing data distribution, including data lineage and freshness requirements

R6 Tutorial for software developers describes how to use semantic technologies in SWIM

R7 Ontology modularisation guidelines for SWIM gives guidelines on how different ontology modules can be reconciled into a consistent and coherent "network" of ontology modules.

R8 Scalability Guidelines for SWIM-based applications gives guidelines on how applications using semantic technology can be applied in the ATM domain with good scalability characteristics.

R9 Governance Recommendations for the use of semantic technologies in SWIM describes an overall approach to governance that deals with the emergence and evolution of semantic technologies in ATM. An emphasis will be put on how ontologies can co-exist and co-evolve and how to manage their dependencies with AIRM and other relevant information exchange models.

What is AIRM?

AIRM (ATM Information Reference Model) is a standardised information model for ATM designed to ensure that the information communicated in SWIM is clearly and uniquely defined and well understood. The AIRM comes as a package containing explanatory material and Unified Modelling Language (UML) models and the BEST project will employ these models and related specifications as a basis for the ontology development in the project. The AIRM UML models are structured to satisfy the needs of several different audiences and its use as a common reference. The models promote semantic interoperability between operational experts, systems and services within the European ATM Network.

Semantic interoperability ensures that the precise meaning of exchanged information is preserved and understood by all parties. The AIRM is recognised in the ICAO Global Air Navigation Plan and in the European Union's Pilot Common Project. The AIRM will become a EUROCONTROL specification.

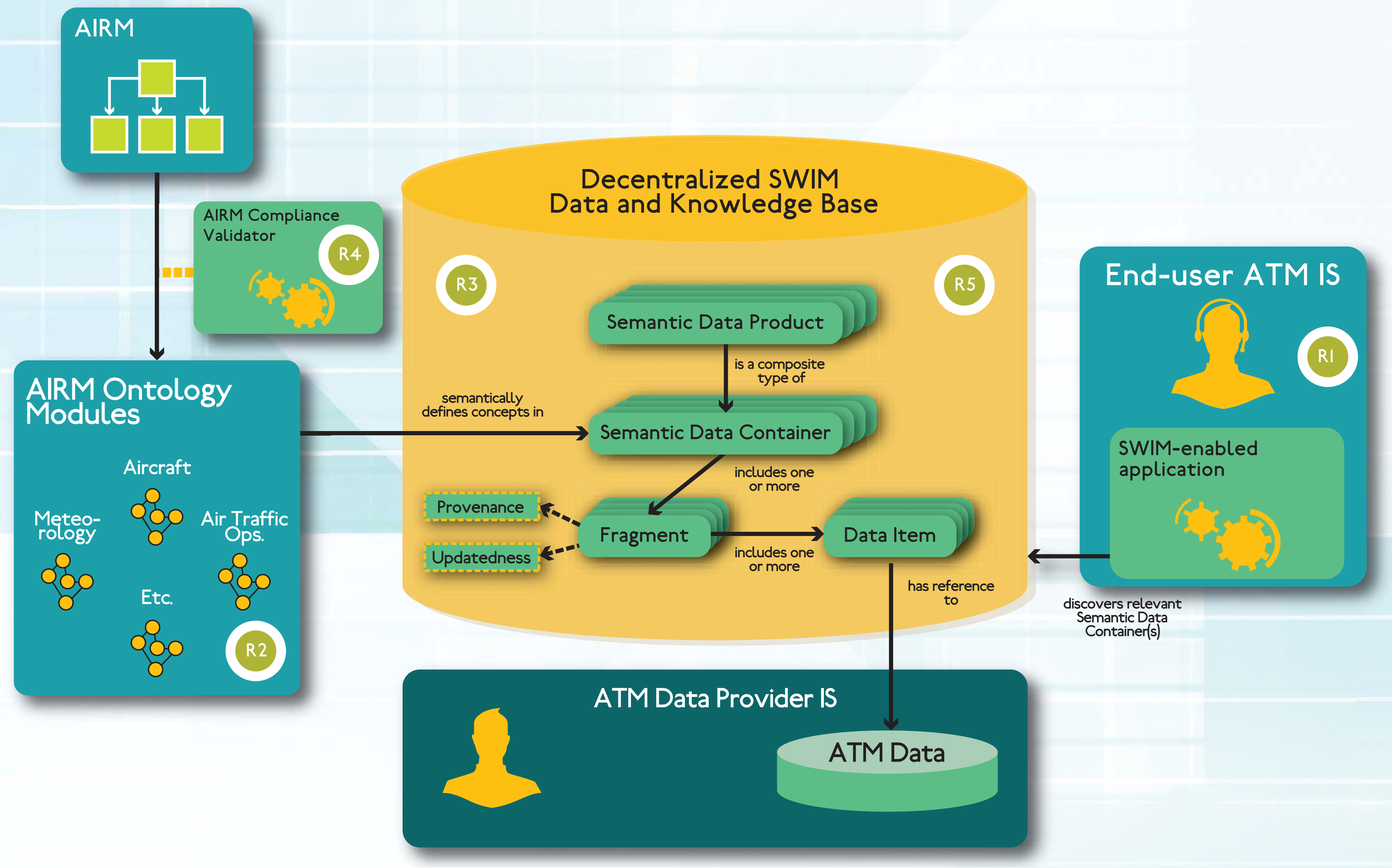
What are semantic technologies? What is an ontology?

Conceptual domain models, such as the AIRM, are typically developed and expressed using the Unified Modeling Language (UML). UML is well-suited to the development of small- to medium-sized domain models, yet practically bound to proprietary tools with only limited support for consistency checking and querying of large models. Furthermore, UML models are typically only used in the requirements engineering and development phase, without proper support for using and changing the models after system deployment and at runtime.

Semantic technologies are a group of technologies that contribute to establishing and employing context associated with data. This is facilitated by linking data with other data through formalized and expressive associations. This enables machines as well as people to understand, share, and derive facts from this interrelated and context-enhanced data at execution time. With semantic technologies, adding, changing and implementing new relationships or interconnecting programs in a different way can be just as simple as changing the external model that these programs share.

Ontologies are formal conceptual domain models with precise and unambiguous concept definitions, fixing the meaning of types, properties, and interrelationships of the entities that exist for a particular domain of discourse. The web ontology language OWL is the de-facto standard for specifying such ontologies and sharing them in decentralized information systems. By using an ontology, the various actors in a decentralized information system commit to the shared understanding of concepts as defined in the ontology, thus avoiding misunderstandings in their communications.

Based on these precise definitions of concepts, off-the-shelf OWL reasoners are used to automatically check the internal consistency of an ontology (i.e. that the statements expressed in the ontology do not violate each other) and to derive the subsumption hierarchy of classes (also known as specialization/generalization/inheritance hierarchies). The subsumption hierarchy relates to how classes in an ontology are organised by inheritance, for example that 'FreightAircraft' is a sub-class of 'Aircraft' and all instances of 'FreightAircraft' are by definition also instances of 'Aircraft' (in this case 'Aircraft' is said to subsume 'FreightAircraft'). Consistency-checking and subsumption hierarchy derivation are two reasoning services that have proven indispensable in the development and maintenance of very large ontologies.



What sort of benefits might using ontologies bring?

Semantic technologies provide the means to describe, organise and retrieve relevant ATM data according to the actual needs of the end-user. This is accomplished by expressive and machine-readable links between metadata concepts (used for describing the actual ATM data) in ontologies, employing these links when organising the concepts in the knowledge base, and consequently supporting the end-user information need by returning data from semantic queries utilising the associations in the knowledge base.

While the communicated data itself will be expressed using standardized exchange data models (such as AIXM, FIXM, iWXXM), the data describing the data (the metadata) is defined according to one coherent vocabulary, represented by the AIRM ontology modules developed in BEST. Thus, the semantic applications do not interfere with the standardised exchange data models.

The BEST decentralized knowledge base, which applies the metadata concepts of the AIRM ontology modules, includes a set of mechanisms that filter and retrieve the available data with respect to relevance and appropriate data distribution strategies. In combination with the concepts expressed in the AIRM ontology modules, the knowledge base assists the user in formulating the information need and in providing the most relevant information according to this need.

Will the project produce any tools or demonstrations?

The project will develop a prototype application that will be demonstrated to and tested by the SWIM community. The prototype will demonstrate how the ideas and developments in earlier parts of the project can contribute to realise the benefits of semantic technologies in a SWIM setting. Furthermore, the prototype application will be evaluated with respect to its scalability in such an ATM environment, and how the composition of the underlying semantic building blocks (i.e. the ontologies, the knowledge base and the data distribution strategies) can best be organised.

Furthermore, the project will develop a compliance validator application that will help assure that ontology modules used in semantic applications are compliant with the standardised AIRM data models. This helps to detect discrepancies between intended and actual usage, and to ensure that the AIRM data models and the ontology infrastructure can co-evolve.

What progress has been made so far?

The early technical work has been focused around establishing an ontological infrastructure composed of ontology modules that will be utilised by the solutions developed in the project. The transformation from AIRM to such ontology modules is accomplished using a set of transformation rules defined within the project, as illustrated in the figure below.

These rules ensure that the semantics expressed in the AIRM data model (represented in UML) are preserved in the resulting OWL ontology modules. The ontological infrastructure is a result that goes beyond the BEST project, and will be publicly available alongside guidelines and tutorials describing how it can be applied together with semantic technologies in other settings.

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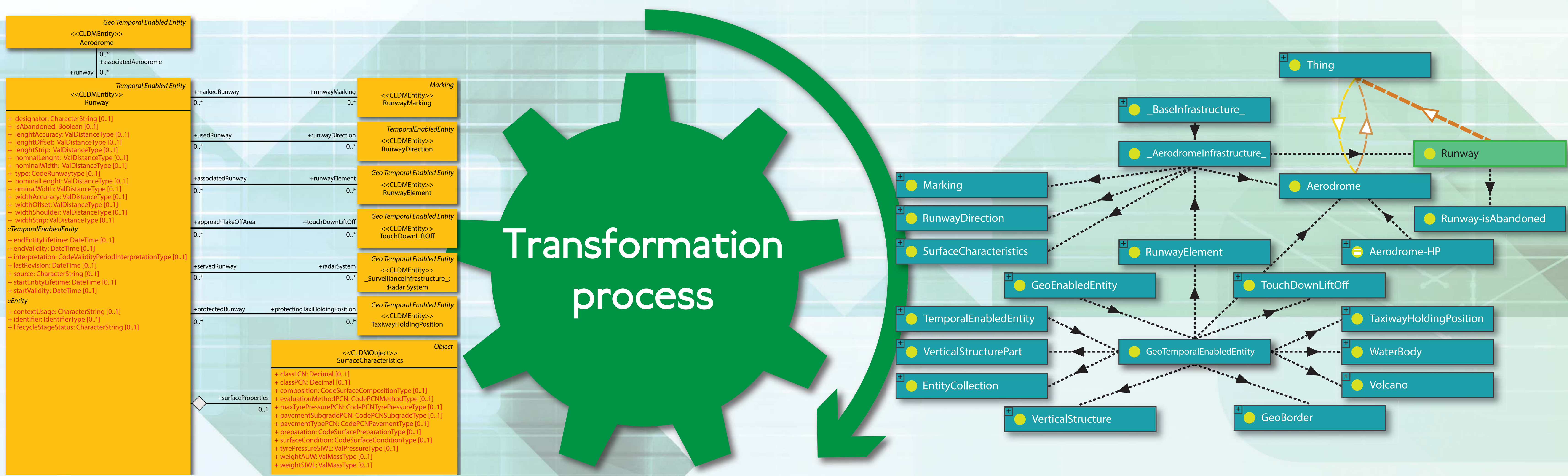
AIRM UML | AIRM OWL



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