# Ontological Approaches for Scaled MBSE Deployment

## Objectives

https://indico.esa.int/event/407/page/602-objectives

**O-3** Sustaining MBSE after first adoption (e.g. long term maintenance and model evolution, application / re-use in the next project, identified non-technical and governance aspects [see also tactical and strategic level])

**T-3** Showcase novel approaches to MBSE that have the potential to significantly improve the state-of-practice in space mission design and development; both innovative approaches from industry and academia are welcomed, but with a clear focus on application potential at scale

**T-4** Discuss the role of existing, evolving and emerging standards to address interoperability and semantic modelling to support digital continuity

## Introduction

MBSE practices are today highly recognized for their significant contribution to digitalize, standardize and structure System Engineering processes. By making possible the traceability and ensuring consistency between engineering artifacts, they prevent design discontinuity, reduce information silos and enable early integration thanks to an authoritative source of information. What makes also MBSE valuable for complex system manufacturers like Airbus Defence & Space, is to leverage model exchanges. Model exchanges can support the co-engineering between space and ground segment or with engineering specialties contributing to the design such as RAMS, cybersecurity, configuration management etc. In the context of model-based deliveries to the customer or between Large System Integrators, digital deliverables (unlike document-based deliverables) improve the quality of the deliveries and foster trust between stakeholders.

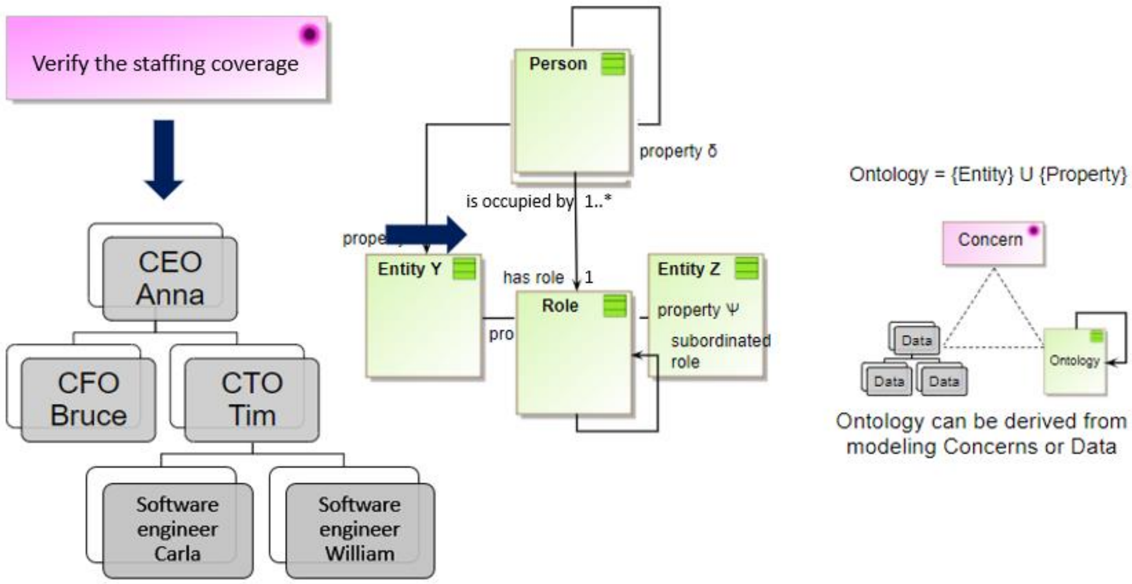
Reuse and model exchange imply to have a shared, reliable and sustainable standard to support interoperability. Within a competitive environment such as the aerospace industry, the modelling frameworks used by the partners must be capable of adapting and interconnecting according the languages, practices and norms evolutions and tooling strategy. Ontological approaches offer an abstract layer on top of the standard languages and notations and hence allow to provide flexibility and resistance towards implementation choices and to capitalize knowledge over time. The main idea is to have tools speaking the language of the stakeholders (concepts and relations defined by the ontology), not the opposite.

Architecture Frameworks like UAF, NAF, DoDAF come with ontologies that support the architecture definition in the Defence domain. They were created to provide homogeneity between architectures in order to perform an accurate comparison. They have proven their worth to “serve as a lingua franca as it provides a unified way of describing complex real world objects” [NAFv.4 documentation version 2020.09]. Along these lines, in the aerospace community, ESA working group OSMoSE aims at developing a Space Systems Ontology to enhance semantic interoperability across Space industry partners (https://mb4se.esa.int/OSMOSE_Main.html) .

## How is applied Ontological approach?

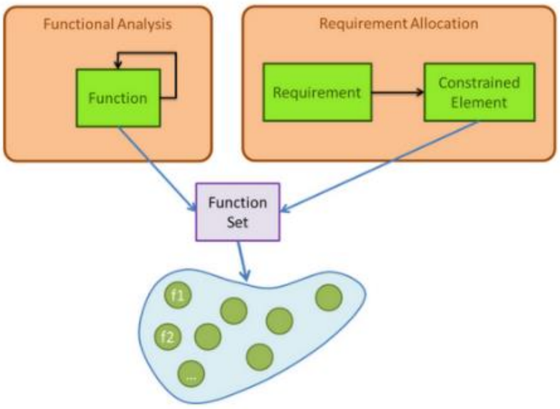
An ontology defines a language-independent and tool-independent model containing the concepts related to a domain area and the properties defining how they are related.

The approach to use ontologies with MBSE is the following. First of all, for a given project, stakeholders shall identify the concerns to be addressed by the architecture model. Why do I model? What is the perimeter of system(s) being modelled? Who will contribute to the model? What do I want to analyse or demonstrate with a model? By answering those questions, the conceptual entities and their relations are derived to form an ontology. For example, « Verify the staffing coverage » is a concern implying to represent entities such as 'Person' and 'Role', as well as the properties materializing the assignment of a Person to a Role and the hierarchical relationships between roles. Thanks to the ontology, it becomes explicit the fact that a person is assigned to only one role but that several persons can occupy the same role (ex: software engineer).




Next, the concepts and relations are depicted in views according to the relations or viewpoints that should be highlighted to answer the concern or objective set in the first place. Concerns used as a driver for defining the scope of the model help to apply MBSE efficiently and to concentrate efforts on producing modelling products that are really valuable for the project.

When the ontology is built, there comes the ontology implementation. In this phase, the elements of the ontology (the concepts and properties) are mapped to the implementation elements proposed by a given modelling language. Implementation elements refer to the modelling tool objects that will substantiate in a digital format the objects created and manipulated by the modeler. For instance, a implementation element can be an Activity in SysML, a Business Process in BPMN, a Block in SDL, etc. Even when they implement a standardized language, the implementation elements are meaningless in terms of system engineering domain. Realizing the mapping between implementation elements and the ontology is a way to give them a semantics, so that the population of the implementation elements actually capture a relevant and meaningful model of the subject of interest. For instance, a SysML Activity can be mapped to a Function (ontology concept) and also to a Constrained element that is linked to Requirement in order to make the Function traceable to a Requirement. The implementation can go from a simple mapping to a full customization of existing tool or language elements to reflect the ontology: renaming, icons, extended properties, check rules etc. The mapping should be done between concepts of the ontology and the implementation elements of the tool (not individuals that populate the model) and may include filters on the name, location in the containment structure, properties etc. This fact is important because it makes the ontology not dependent of the size of model population.




As a result, the end-users uses tools are customized in order to reflect their domain concepts and representations. In addition, we can evaluate the model maturity and completeness by evaluating if the views produced satisfy the concerns initially targeted by the project. At ADS, several formal quantitative assessments have been realized on some Defence projects. On Space projects, even not yet formal, qualitative assessments help to measure the progress and maturity of both the modeling data and activities.

## What are the benefits of an ontological approach?

First and foremost, the use of an ontology, even not directly implemented inside the tools, helps to achieve a common understanding of the problem to solve. Modelling is an activity that requires abstraction and conceptual faculties and consequently, it involves necessarily the subjectivity of the modeler. An ontology establishes a common frame for all contributors of the same project to represent the engineering artifacts. Therefore, it makes the individual contributions consistent together into forming a non-ambiguous model. From the reader point of view, the ontology can serve as a “reading guide” for reviewers that may not have an expert knowledge of modelling languages.

The great strength of this approach is that it is tool-agnostic and language-agnostic. It makes model exchanges possible in case of toolset evolution or in the context of exchange with partners that are not using the same tool. As long as the mapping between the ontology and the different implementations of destination is done and shared by all stakeholders, then the model transfer is available without semantic loss. In ADS, we are undergoing a major MBSE tool evolution. The migration of models from one tool to another will be supported by ontological approaches in order to automatise as much as possible the data conversion.

Actually, when combined with tools, the ontology gives body to the existing implementation elements to build an ad-hoc profile that matches the domain concepts. It is a great opportunity to involve engineering specialties such as RAMS, cybersecurity, integrated logistics support, IVQ…) to contribute to the system model by introducing their concepts in the ontology. A single element of the model population (what we call an individual) can then be accessible through different entry points, depending on the viewpoint adopted. This goes along with the efforts to promote the adoption of model-centric processes. A concrete example of this aspect is the modelling of synchronous and asynchronous interfaces in an ADS navigation project. The definition of an interface is different in each case. In the first case, a synchronous interface is represented by the interaction link object that connects two components together. The concept “Synchronous Interface” is then easily mapped on the implementation object used to populate interaction links. Consequently, we count the same number of synchronous interface individuals as interaction link objects. In the case of Asynchronous interfaces, they are represented by a set of several functional data of the same type (monitoring, commanding…) that are sent or received by a component. As a result, a given set of similar data exchanged between two components will be used to define two different asynchronous interfaces, one for the emitter and the other for the receiver. The ontology is here very useful to express this asymmetrical interface definition and facilitate the collection and display of the individuals of each interface concept.

Lastly, the ontology acts as an enabler for model exploitation. By exploitation, we mean model analysis and export. One of the major benefit of MBSE is that the design and architecture of a given system is saved through a digital support. The interrogation of the model information and data extract is then made possible by means of queries and export facilities (depending of course of the tool). We have seen previously that building the ontology offers the capability to form set of elements that make sense for the area of interest. The sets can then be reused as input for queries, document generators or analysis reports. The power of having ontology-based exploitation features is that they don’t rely on the model population and can be easily replicated from an environment to another. In the project EGNOS V3, several documents officially delivered to ESA are generated from the model and rely on the project ontology. The DDF and ICD automatic generators are configured with queries that loop on the entity individuals of the ontology and display the relevant information. This ensures that when the model content is updated, the data collected by the generation structure is automatically updated accordingly.

## Next steps

Ontological approaches have shown their value when applied on large system models. However, their usage is not yet widely spread on all Space Systems projects for multiple reasons. First, in some projects, MBSE has still not been fully adopted. People are still experimenting, skills are ramping up, and therefore it is sometimes too early to introduce such abstract practices as ontology-based engineering.

Even on project that uses an ontological approach, it is difficult on very large and complex systems like EGNOS V3 to maintain the proper methodology describe above. The concerns have been partially set, the model is not assessed in comparison to these objectives and the ontology is mostly driven by document generation and report analysis rather than the capture of all engineering concepts.

Nevertheless, the Airbus internal initiative DDMS actively promote MBSE practices and the deployments on the new framework are multiplying across Airbus divisions. Ontological approaches are strongly pushed for new projects to ensure common understanding, model sustainability, and make the most of the model in terms of analysis and extract.

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