Enhancing the MBSE-Hub for AIV Reporting Needs

The process on how to arrive to an AIV Ontology compliant with the Space System Ontology and generate reports for AIV Engineers related to workshop objectives O-5 and S-2.

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Extended Abstract

Introduction

The application of Model-Based Systems Engineering to manage the growing complexity in system design and development starts at the beginning of a project on the left side of the Systems Engineering V-model by conducting analysis of the problem and the potential concepts on functional and logical level all the way down to specifying the concrete technical solution on physical level. However, little application is currently seen in the space industry to apply MBSE as support for the activities on the rights side of the V-model, i.e. for assembly, integration and testing/verification and validation.

The objective of the Model-Based System Engineering for AIV (MBSE 4 AIV) project, subject of this paper, is to bring the same principles and related benefits to this later project phase activities by creating a single-source of truth for AIV relevant information capture and exchange between different tools for on/off-site AIT test campaigns to avoid manual work and inconsistencies.

The production of a tool suitable for the reporting of AIT and Verification activities using a language understood by all parties is, thus, the final goal of the project.

But, how will all parties share the same understanding? And how can the documentation of such understanding be automated? The answer to those questions implies the digitalization of the engineering tasks throughout the lifecycle. Digitalization of the information will allow automation and ensure data persistence while conceptualization will provide interoperability. Both topics are involved within the MBSE domain, which is core to this development and roadmap.

In 2017 a collaborative effort between the Agency and the LSIs, took place to define an ontology focused on the reporting needs for AIT & AIV stages. During this effort, a comparison of the contents of real reports created (mostly manually) and used by the LSIs was performed. it was clearly seen that while the different reports shared some commonalities, the required contents of test reports differ significantly across departments and test activities, and none of the inspected test reports achieved a complete coverage of the required content as defined in ECSS-E-ST-10-02C. Furthermore, the LSIs identified missing contents on manually creation which were deemed useful and should be added.

From that analysis the following was drafted:

- requirements for a software reporting system,
- user stories representing the expected features and

- a data model named Test Report Standard Ontology (i.e. TRS) [1].

That specification and the resulting ontology have been used as the basis for this project.

This paper presents the ongoing work for the creation of a conceptual data model able to capture all relevant AIV knowledge. From that model, physical schemas will be automatically generated to be used for the digitalization of the involved data and for the definition of exchange interfaces used by the future developed AIV reporting tool which will have to satisfy selected AIV Use Cases.

Use Case Definitions

For the validation of the report generation tool, OHB defined a set of Use Cases explaining the features the future AIV report generation tool will need to provide. Each Use Case specifies how their AIV engineers and experts would interact with the tool to request different types of AIV reports by the selection of different parameters and which would be the expected outputs.

In most cases, these reports do not exist yet as currently the information is spread over different document and tools. The definition of the targeted reports has been an effort to identify nice-to-have/desired capabilities instead of replicating current mechanisms (which have not always proven to be efficient).

The following use cases have been drafted by OHB:

- Generate Status Report exposes an overview of the number and status of certain concept types per system element (traditionally displayed in XY plots).
- Generate Verification Status Report provides an overview on the verification status of a Project or a specific Requirement Specification Document.
- Generate TimeLine Report provides a timeline view based on parameters from an input project schedule showing different selectable milestones.
- Generate Milestone Report provides a set of customizable parameters which characterize a specific Verification Milestone.
- Generate Procedure Summary Report providing a summary and status of a procedure.
- Generate Test Specification Summary Report provides a summary and status of the test specification depending on parameters related to the Procedure concept.
- Generate As-Run Report Summary provides a summary and status of the test report

Conceptual Data Modelling

Parallel to this project, a Space System Ontology (SSO) [2], led by ESA is being modelled. That ontology development is coordinated by the so-called "**O**verall **S**emantic **Mo**delling for **S**ystem **E**ngineering" Governance (OSMoSE) for ensuring semantic interoperability between all partners. As the Object Role Modelling Method (ORM) [3] through the NORMA Tool is being used for the Ontology development, the conceptualization of the AIV Reporting semantics has applied the same methodology and tools to facilitate the future integration of the resulting conceptual data model will be integrated) in the Space System Ontology.

ORM is a powerful method for designing and querying information models at the conceptual level, where the application is described in terms easily understood by non-technical users. ORM data models not only represent data relationships (e.g., which maps to the traditional database columns) but often also captures business rules and are easier to validate and evolve than data models in other approach.

The SSO will integrate different Universes of Discourse (UoD), including the conceptual model resulting of this project.

Within the MBSE4AIV, the conceptual modelling exercise was performed in two separate ways in order to represent and align on one side, the knowledge already captured by the TRS data model on a top-down approach, and on the other, the practical updated needs of the industry which shall be demonstrated with real examples (on a bottom-up manner). These two opposite direction approaches have been merged in a single conceptual model. During which, collisions, assumptions and also modelling training has been provided to the AIV experts which needed to validate the resulting models.

As such, an agile modelling effort has been applied. Draft models were created, updated and delivered to ESA and/or to AIV Experts for further review including those against the latest status of the SSO model. Upon comments, modifications were performed in several iterations until no more concerns or problems were raised.

Top-Down Approach

The Top-Down Approach was performed by taking the OWL and UML representations of the TRS and translating the terms/relationships defined into concepts and fact types.

Conceptualizing a UML Class diagram requires not just modelling experience but also domain specific knowledge. This is due to the involvement of not just the data, but constraints, processes, behaviours and different perspectives on the use (e.g. ownership, navigation, etc). In order to perform such task, an agile incremental set of steps were followed including expert validations of the model.

Following those steps, the resulting conceptual model contains 105 explicit different concepts, more than 110 fact types (i.e. relationships) and constraints. These numbers do not include those concepts, fact types or constraints imported from other Universe of Discourses.

Bottom-Up Approach

During the top-down approach in which the first version of the AIV conceptual data model was created, several issues were discovered including inconsistencies, missing information or concept collisions with other concepts already existing in SSO. This rendered the model incomplete and inconsistent as there were semantic errors which had to be solved.

In order to solve as many issues as possible, AIV Experts were interviewed. However, most of the problems could not be resolved due to three main reasons:

- The TRS project was performed several years ago before the idea to use MBSE methods and tools for improving interoperability and software development was agreed and accepted. Although it was a good first step to identify issues and try to find a common ground for AIV; most of the semantics and explanations are missing as it was based on a document-centric traditional approach.
- The people involved on that project is no longer available to retrace the discussions leading to modelling decisions.
- The state of the art of inter-connected UoD has also changed quite a lot in the time since and new data models (e.g. EGS-CC), needs (e.g. stronger security protocols) or process improvements have been implemented since.

With these issues at hand, it was decided to augment the initial concept model with the semantics required to satisfy the type of AIV Reports involved in the Use Cases through agile meetings with UC AIV experts.

As a result of this bottom-up approach, 52 new concepts were added to the model, 141 new fact types and 10 constraints. This means, the model has been enhanced almost doubling its size from the top-down approach.

Exchange Interfaces

In order to ensure that the AIV information can be disseminated between the customer-prime-supplier chain with complete understanding, a comprehensive data exchange interface(s) will need to be defined based on the conceptual data model created.

Levels of the exchange interfaces will also be impacted by security constraints and the level of granularity desired and agreed between parties. As a consequence, it is foreseen to define a generic interface with the minimum conceptually meaningful information and another (i.e. the native one) which enables complete exchange also of any referenced data which may belong to another UoD.

The technology for the definition of the interfaces will have to be aligned with the one used by the MBSE Hub as this will be the preferred mechanism used, for demonstration of the exchange.

Conclusions

The MBSE 4 AIV Project has already identified the issue that the scope of the AIV knowledge is related with many other Universe of Discourses which may cause concept collisions and implementation problems if the semantics differ.

Therefore, there is a need for data harmonisation and a fast iteration cycle for the governance of the different UoD to avoid collisions, misunderstandings or assumptions not captured in the models.

Without an automatic manner to pull and integrate all UoD into one (due to technology constraints on the chosen methodology), it is a realistic risk that whatever software is developed for the AIV domain or any other UoD; cannot be aligned within the hub if they change their own conceptual models. This will have a big impact in terms of time and cost which can reduce the adoption of the methodology and the hub itself by industry and agencies alike Thus, one of the first subjects to target is to de-risk this situation with an agreement between parties.

At writing time of this paper, the project is on the review process of the conceptual data model and the creation of the technical specification and the exchange interface definition. The development and demonstration of the project is foreseen to finish during Q2 of 2023.

References

[1] Test Report Standard, https://indico.esa.int/event/201/contributions/1864/attachments/1599/1846/1000b_Test_Report.pdf

[2] Space System Ontology (SSO) https://mb4se.esa.int/OSMOSE_Space%20System%20Ontology.html

[3] Object Role Modelling (ORM), http://www.orm.net/