Objective: T-2 and T-3

Model Based System Engineering Hub

Short paper for MBSE 2022 Conference

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The envisioned way to implement digitalisation in the European space industry is in the form of MBSE System Factory, an integrated software and hardware infrastructure to support the MBSE process. The objectives of the System Factory are to streamline the space system development process across the entire life cycle, i.e., shorten the development time and reduce costs of projects, manage the increasing complexity of space missions, and offer process guidance and automation to support the development of ECSS compliant space systems.

There are many tools used in model-based activities in different engineering disciplines, but the exchange of information is typically done by manual processes, which has the disadvantages of work duplication, low automation, and lack of data normalisation. The plan to overcome these challenges is to develop a centralised Hub (at the centre of the System Factory concept) that provides interoperability between the different stakeholders and tools. The Hub would be used by different levels and disciplines of engineering, as well as throughout different phases of a space project, and it shall allow the stakeholders to exchange information using a common vocabulary described in the Space System Ontology (SSO). In addition to providing interoperability, the hub needs to support auxiliary processes, such as authentication, authorisation, configuration control and enforcing correct workflows. The concise set of user requirements put forward by the Agency includes such complexities such as data version comparison, branching, federated deployments of connected Hubs and data validation against the SSO.

The first prototype implementation of such a Hub is currently being developed in the Model Based Engineering Hub (MBEH) project by a consortium consisting of RHEA Group, OHB, Thales Alenia Space. DEKonsult is providing consultation throughout the execution of the activity. The overall objectives of the project are to scope and specify the MBSE Hub, provide a technical solution for it and to demonstrate its functionality with two use cases from different domains.

One of the selected domains to define realistic and beneficial use cases for the MBSE Hub is the Operations Domain and in particular for the facilitation of typical data exchanges with the Systems Engineering. A thorough analysis of the OPS-ENG exchanges covers ten pre-selected use cases with a wide range of applications from requirements management over subsystem-models for simulation to test data and anomaly reports. The identified core interest from the involved OPS experts was though the use cases related to the exchange of flight operation procedures and connection to Mission & Control (M&C) data from a reference database. In this analysis the typical involved actors, tasks to be conducted and related

exchange items are described based on common standard processes on Ground Systems and Operations (i.e., ECSS-E-ST-70C), existing or evolving tools and data formats as well as a realistic description of current workflow and inefficiencies related to document-based exchange or incompatibilities between different tools/formats. A very promising current development at ESOC is the Procedure Exchange Format with heritage from the PLUTO language and compatible with EGS-CC CDM implemented in XML.

For the identified exchange items from the use cases, a detailed description of the expected information types and tools and data formats/schemas has been prepared. In close relation to existing descriptions in OPS related ontologies (i.e., ORM models of ECSS-E-ST-70-31/32/41), an inventory of existing matching concepts has been created and gaps to be implemented in the next phase of the project have been identified.

For the validation of the MBSE Hub prototype a demonstration case has been defined and scoped to a cover a realistic but still achievable scenario focusing on the implementation and exchange of FOPs and extending to other closely related use cases by establishing reference to related exchange items. The proposed demonstration scenario will start with a creation of a Space System Model, representing the decomposition of the System in a System Engineering tool (e.g., COMET, Capella, EA/CAMEO) and extended with related parameters and references to requirements. A procedure skeleton by means of main steps, included activities and events associated to the different Space System Model Elements incl. exchanges between space and ground (i.e., Telecommands/Telemetry) is defined by the System Engineering team. This Space System Model and the procedure skeleton shall be uploaded to the Hub by respective adapter and translated into a SSO representation, from where it can be exported into different formats required by other tools, in particular for the OPS domain. The Space System Model shall be imported into the OPEN-M preparation environment to populate the EGS-CC CDM with regard to M&C elements and attached parameters and activities.

It is further proposed to combine the selected core use case for the Exchange of FOPs with smaller aspects from selected Use Case(i.e., requirements, mission constraints and test / validation data). The creation of a global model inside the hub allows for linking of model elements from different environments and formats. Relationships between FOP related elements and other artefacts enable direct tracing, identification of dependencies and consistent documentation of test and validation status. The overall setup of the use case incl. Directly and indirectly involved tools (or future evolutions) is shown in Figure 1.

Similarly, the Reliability, Availability, Maintainability and Safety (RAMS) domain went through the same exercise to determine exchanges involved in a model-based multi-disciplinary tradeoffs based on mass, cost and reliability Capella viewpoints developed by Thales Alenia Space, combined with FDIR and FMEA analysis. A link with operational data in this regard is also established. Since the typical workflow of RAMS analysis for the most part is still done in a classical document-based approach, a new model-based method is being proposed for the purposes of the demonstration.

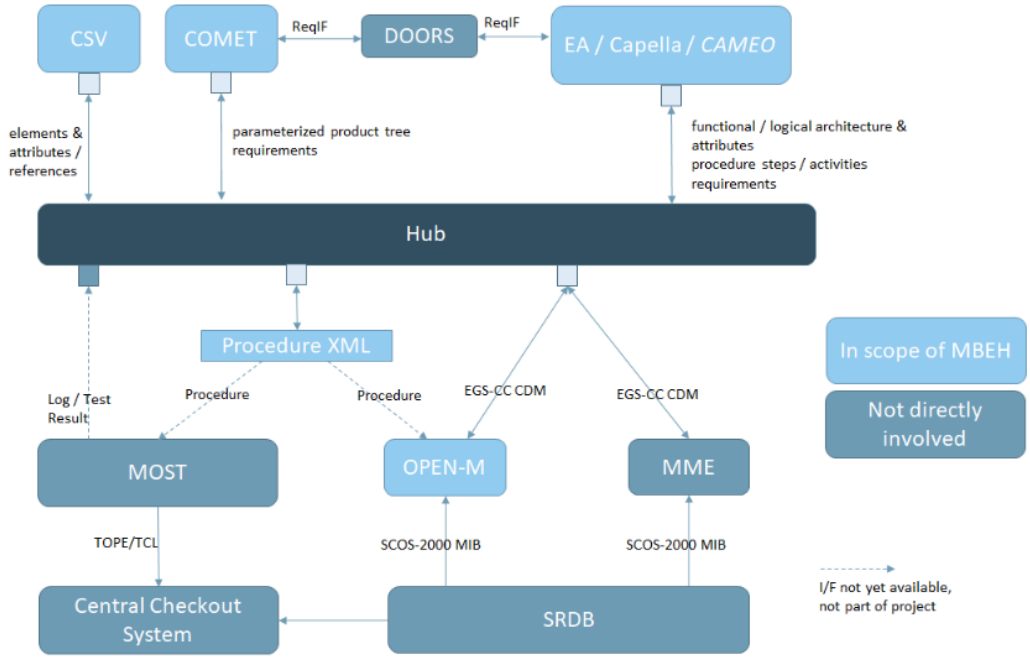

Figure 1: Tools and Formats Involved in the Operations-System Engineering Exchange

The outputs of the identification of the exchanges for both domains will be used to develop the corresponding Universes of Discourse as supplements to the models already being developed in the frame of OSMoSE. The ontology supplements will be done in Object Role Modeling using the NORMA Pro software to ensure full compatibility. The completed models will be presented to the MB4SE and OSMoSE working groups at Preliminary Design Review for approval. An in-house open-source library called Kalliope[1] is being developed by RHEA to be able to parse and compose ORM2 compliant files in order to use the formalized information in custom code-generators to automatically produce logical and physical models based on the SSO by the MBSE Hub implementation. This is done to ensure the single-source-of-truth principle used in the model-based software engineering approach that RHEA takes in most of its developments. An example of this fully automatic generation can be seen in Figure 2.

[1] https://github.com/RHEAGROUP/Kalliope

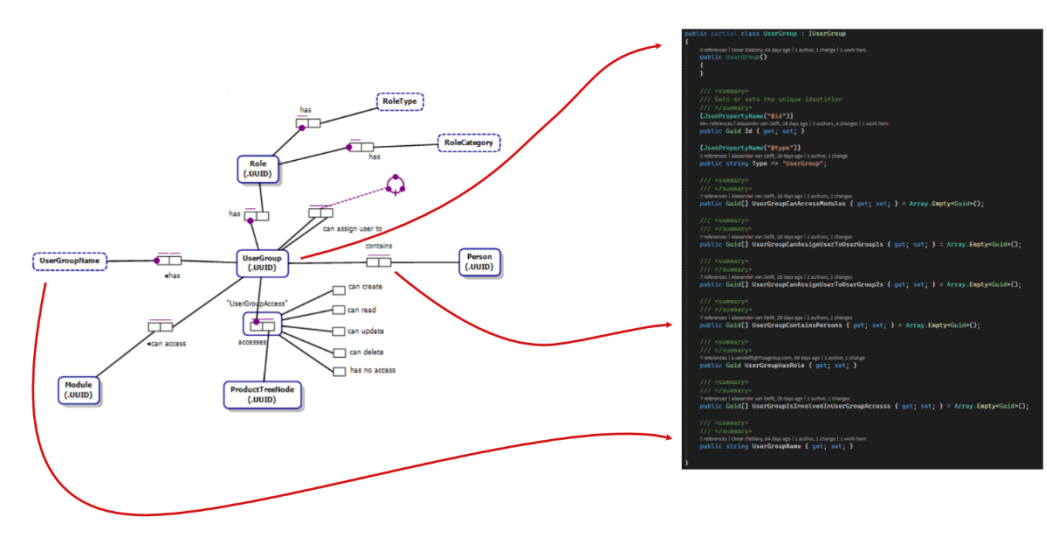

Figure 2: Automatically Generated Data Transfer Object Based on ORM Model Using Kalliope

The exchange of engineering information from source authoring tools is achieved in several ways. Biggest flexibility is achieved by creation of specific adapters for the particular tool. The adapters, on the one hand, interface with the tool or the exchange file on the user's workstation, and on the other with the MBSE Hub through its native API. This hub-and-spokes model was successfully demonstrated to work in the related Digital Engineering Hub Pathfinder (DEHP) activity, performed by RHEA, OHB, Astos and Open Engineering, in which ten adapters were built for various industry standard 3rd party modeling and simulation tools, and used the E-TM-10-25 COMET server as the centralized repository to exchange with. The power of independent adapter is such that they can provide segregated, maintainable capabilities independent from the developments of the MBSE Hub itself. DEHP adapters showed that they are able to operate on a common core architecture, have ability to do partial transfers, perform complex mapping, inspect impact on the target model and maintain exchange history. This activity successfully concluded in the summer of 2022.

The second way to exchange data is through uploading the information artifacts (complete files) to the MBSE Hub directly, together with some standardized mapping instructions. This would be appropriate for instance for CSV, ReqIF or certain XML formats. The Hub architecture foresees a pluggable infrastructure for conversion plugins that would automatically detect the appropriate format and carry out the transformation to the native Hub model.

The deployment of the MBSE Hub would see it installed on a server alongside a message broker component. The message broker will facilitate the full exchange of engineering information with other federated instances of the Hub, potentially installed on other remote infrastructures in a push fashion. When a secure connection is established, a pipeline through a message queue is created that serves to create and update instances on the secondary site. Once any number of objects are shared, their ancestry is persisted and any updates on the master are instantly propagated to the share endpoints. An exchange loop is achieved by creating the connection in the same manner from the other Hub. To ensure the security of the federation, all message queues would be protected by certificates issued by a central authority.

All of the above is demonstrated in the deployment diagram in Figure 3. The left side of the figure illustrates the model authoring tools that have been identified to be in the scope of this activity. The intent is to reuse a substantial number of ideas and components that have previously been developed at RHEA during the development of the Model-bAsed Requirements Verification Lifecycle (MARVL) Common Information Platform.

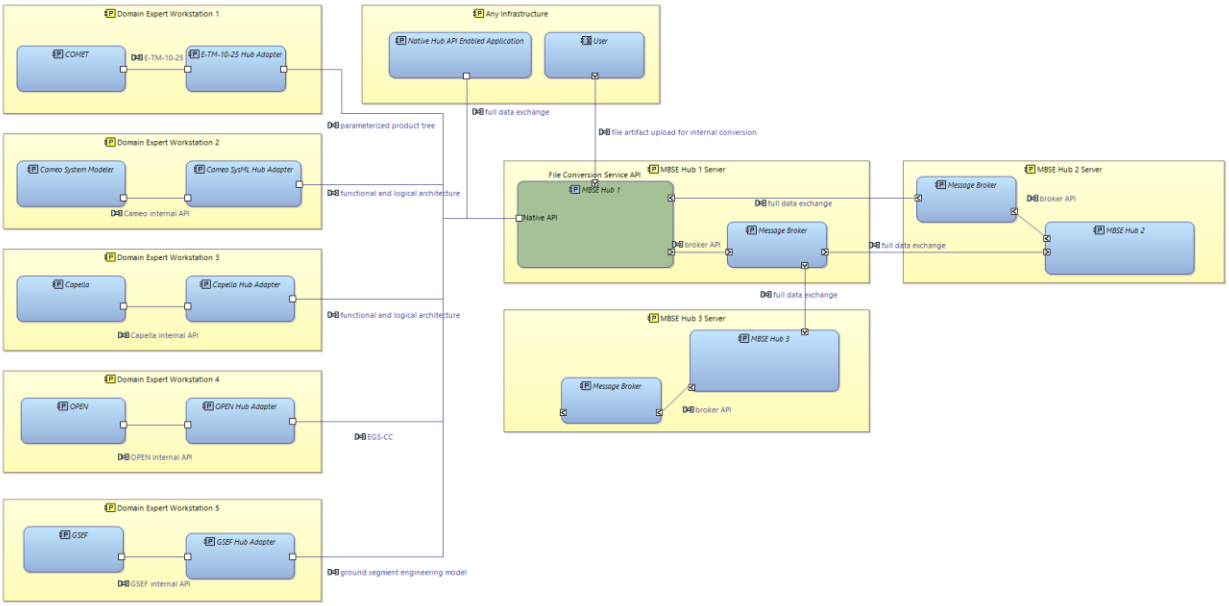

Figure 3: MBSE Hub Deployment Architecture

The activity is intended to run until the end of the second quarter of 2023 and is now firmly in the software design phase of the project. The operations and reliability ontology universes of discourse are being developed in parallel on top of the ORM artifacts received from other OSMoSE activities to ensure full compatibility in exchanges. The development team, at the same time, is evolving the architecture to meet the ambitions of the project. At the Preliminary Design Review slated for end of October the consortium will present the results of this work, at which point the development will begin. Following established agile practices, the consortium plans to conclude with a demonstration phase starting in March and April of 2023. The software will be available under ESA Community Permissive License (Type 3) and maintained though the ESA GitLab infrastructure, exchanging relevant developments with parallel activities in an open fashion.