TeePee4Space : a practical application of Information Sharing in Extended Entreprise to the space industry

Julien BACLET
Romaric DEMACHY
Sébastien GUILMEAU
julien.baclet@irt-saintexupery.com
romaric.demachy@irt-saintexupery.com
sebastien.guilmeau@irt-saintexupery.com
IRT Saint Exupéry
Toulouse, France

Pierre GAUFILLET
Jean-Luc MARTY
pierre.gauffilet@airbus.com
jean-luc.marty@airbus.com
Airbus Defence and Space
Toulouse, France

Gérald GARCIA
gerald.garcia@thalesaleniaspace.com
Thales Alenia Space
Cannes, France

Jean-Marie GAUTHIER
jm.gauthier@Samares-Engineering.com
SAMARES Engineering
Blagnac, France

ABSTRACT

The federation of systems engineering modeling artifacts in the context of Extended Enterprise (EE) is an opportunity to accelerate system design and to increase the consistency of interactions between involved stakeholders. Each company of the EE has its own methods, languages, and tools to specify, develop and manufacture complex systems. Furthermore, information sharing in en EE context shall not be improved at the expense of the intellectual property protection. Therefore, dealing with multiple layers of stakeholders in a EE providing heterogeneous and distributed models while ensuring intellectual property protection are key challenges that need to be addressed by new industrial collaborative solutions. This paper presents our proposal towards an information sharing solution, which enables heterogeneous and distributed model federation through the whole supply chain. This solution is currently being experimented on a space industry context by the TeePee4Space project, led for ESA by IRT Saint Exupéry and involving Thales Alenia Space and Airbus Defence and Space.

1 PROBLEM STATEMENT

In order to take a correct decision at the right time, the collaborating companies need to feed their decision management process with federated SE data coming from their own data warehouse and from their direct and indirect partners. Addressing this need in a dynamic manufacturing network context is challenging, especially when SE data are modeling objects. Wouters et al. [10] have identified some of the challenges of the application of MBSE in a collaborative engineering context, which we have adapted and are summarized below :

- **C1 Build a shared vocabulary:** the identification of common concepts shared between the EE stakeholders. A strong attention shall be given to the meaning of those concepts projected onto the data.
- **C2 Specify the collaboration in the extended enterprise:** This challenge refers to the specification of EE's exchanges. It shall contain requirements about the expected collaboration method between each collaborating company, and about the orchestration of flows that are produced and consumed by each collaborating companies.
- **C3 Controlled data exposure:** For instance, a company shall expose the minimal set of data needed to answer a specific demand expressed by another one in the EE.
- **C4 Consistency of the exposed data:** the constraints that shall be respected by collaborating companies to ensure the federation of SE data over the EE will be consistent. It relates to different validation activities performed under version control to detect and manage inconsistencies between SE data coming from different stakeholders.

2 SOLUTIONS TO CHALLENGES

In this section, we describe our solution to support the federation and analysis of SE data through an Extended Enterprise (EE) network. The proposed approach, called TeePee, has two major capabilities. The first consists in federating heterogeneous and distributed SE data. The second is a decision cockpit that enables the analysis and the visualization of the federated data to support the decision process.

Our solution introduces an answer for each challenge listed in Section 1.

2.1 Building a Shared Vocabulary

Since authoring tools (such as Cameo, Capella, or COMET in the ESA CDF context) relies on heterogeneous methods and languages, the TeePee decision cockpit shall implement a shared vocabulary. Hence, we propose to rely on a common vocabulary formalized as a pivot meta-model to ensure the federation of heterogeneous data. Instead of trying to provide an exhaustive mapping with the concepts of the various modeling languages, we propose to define viewpoints dedicated to a given analysis, for which only the modeling artifacts required and agreed between the stakeholders are considered.

This meta-model, called SEIM (Systems Engineering Information Model), specifies, for each System Engineering (SE) analysis viewpoint, the concepts that shall be retrieved from the distributed models to address analysis needs, e.g. mass parameters, interfaces, functions, products, etc.

Then, each company contributing to it can map the meta-model of its authoring tools with the SEIM.

To complete the mutual understanding, stakeholders shall also discuss and agree the graphical representation via glyph, colors, layout, etc. to share a common mind-set on SE analysis results.

2.2 Specifying the Collaboration in Extending Enterprise

The Extended Enterprise emerges when a customer delegate parts of its work to several suppliers according to its "make or buy" strategy. This decision is taken on leaves of a given breakdown structure (e.g. Product, Functional). When a "buy" commitment is taken on a particular leaf, suppliers refine customer data for this leaf. Fig. 1 illustrates an example of a system designed by different companies collaborating through an EE network.

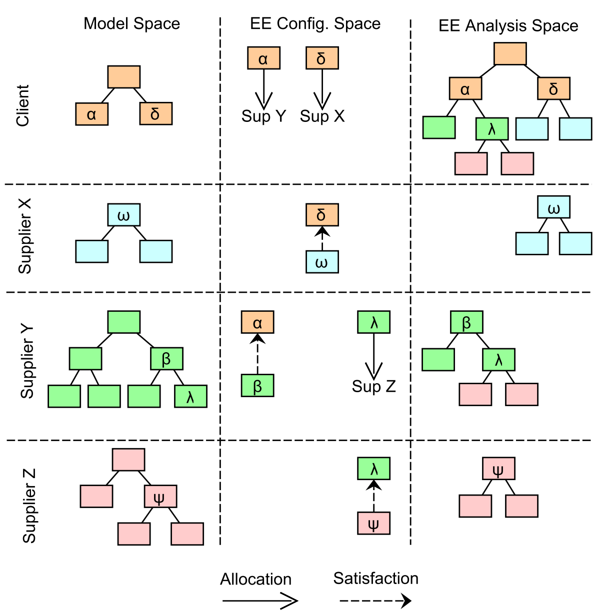

Figure 1: Collaboration mechanism in EE.

Our proposal to manage this refinement of SE data is to mimic what is done for requirements with allocation and satisfaction links. For instance, the customer allocates leaf model elements (functions, sub-system, component, etc.) to its suppliers (X and Y). The suppliers can then satisfy the customer request by providing their model elements. With this kind of EE, the distribution constraint allows the client to get SE data from a Tier2 supplier (Supplier Z) without having a direct contract with it. It assumes however that the contract between Supplier Y and Supplier Z allows Supplier Y to transmit data to the customer.

2.3 Controlling Data Exposure

When dealing with information sharing, many concerns exist (levels of confidentiality, management of IP, export control ruling country trades...) and they are crucial for any company. Thus, each data shall clearly identify their owner and have attributes to cope with these concerns.

In the Fig. 1, supplier Z has a white-box strategy meaning that it exposes everything to its customer, the supplier Y. But in the case where supplier Z want to protect IP on Ψ model artefact, it shall be able to hide (black-box strategy) or filter (grey-box strategy) elements related to it. Access control management shall also be considered to give the right privileges to specific users. In this way, only authorized people shall be able to perform analyses. As an example where all members are strictly isolated from each other, a team from Supplier X shall not be authorized to access data about β model artefact.

2.4 Consistency of Exposed Data

The consistency of exposed data is necessary to perform consistent federation of data, even if not sufficient.

Several principles are implemented :

- A mapping between customer's and supplier's project and version allows achieving consistency regarding the version control aspect at a viewpoint level
- For completeness, the *allocation* and *satisfaction* links illustrated in Fig. 1 allow the coverage checking of customer's model artifacts by supplier's ones.
- For correctness, even if some checks may be performed through the shared SEIM datamodel explained in section 2.1, systems engineers should rely on the analysis results to detect inconsistencies.

3 EXPERIMENT

The methodology and the tool have been developed using an open source case study ([1]) managed by IRT Saint Exupery, in which the system of interest is a Remotely Piloted Aircraft System (RPAS). The aim of the TeePee4Space project is to experiment the methodology and demonstrate the usage of the TeePee tool in the context of an Extended Enterprise structure which is representative of the space industry. In particular, the capacity of TeePee to aggregate data from the COMET tool used at CDF and implementing the ECSS-TM-10-25 framework [2] will be evaluated.-

Several adaptations and enhancements are explored :

- The adaptation of TeePee for a typical space Extended Enterprise composed of an agency (ESA), a Large System Integrator (LSI) and its suppliers
- The creation of an additional connector between COMET and TeePee
- The re-use and possible adaptation of existing viewpoints
- The creation of additional viewpoints of interest in the space context

[1]https://sahara.irt-saintexupery.com/AIDA/AIDAArchitecture
[2]The ECSS-TM-10-25 framework aims at providing common data definitions and exchange among space industry partners

3.1 Case Study

The considered system-of-interest for this experiment is a generic satellite system, composed of a Service Module and a Payload Module. Each module is then composed of several components

Our proposal to federate SE data across the Extended Enterprise (EE) is evaluated on SE data produced during preliminary design phases (0, 1A-B) in which LSI are involved. In these phases, one major expectation from ESA is to assess the conformity of the design proposed by LSIs with high level requirements that are of first importance to assess the feasibility of a mission concept : mass, power consumption, etc...

3.2 Simulated Extended Enterprise Network

To assess the relevance of our proposed solution, we have simulated the EE network of Fig. 2.

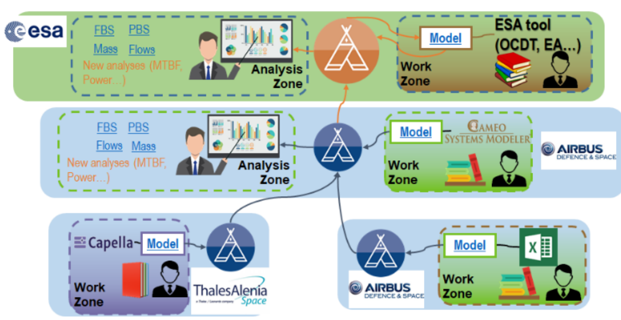

Figure 2: Topology of the simulated extended enterprise.

It shows that the EE network is composed of four companies with two levels of suppliers. The *ESA*'s *Decision Cockpit* provides analyses based on the SE data federated by the various instances of the TeePee tool installed on each supplier premises. Additionally, each supplier may also implement its own decision cockpit.

We assumed that each company of the network creates its models using different modeling tools, languages, and methods from each other:

- ESA model is implemented within the COMET tool, and shows the whole mission level (including ground segment, launcher and space segment)
- LSI model is implemented within Cameo Systems Modeler, following the modeling methodology used by Airbus Defence and Space. This model represent the whole satellite (corresponding to the space segment of the ESA model), assuming the Service Module design is under the LSI responsibility. The Payload module design is under the Supplier responsibility and appears as a black box in the LSI model.
- Supplier model is implemented within Capella, as done by Thales Alenia Space. It represent the detailed design of the Payload Module.
- Other suppliers may be added, using other modelling tools and methodologies

3.3 Results

The TeePee4Space project is still under progress. Final results are not included in this abstract.

The first studied scenario is the aggregation of mass data included in the LSI and suppliers models and comparison with expected masses coming from the ESA model. The figure 3 gives an example of a possible representation of a mass budget analysis, in the form of a sunburst diagram.

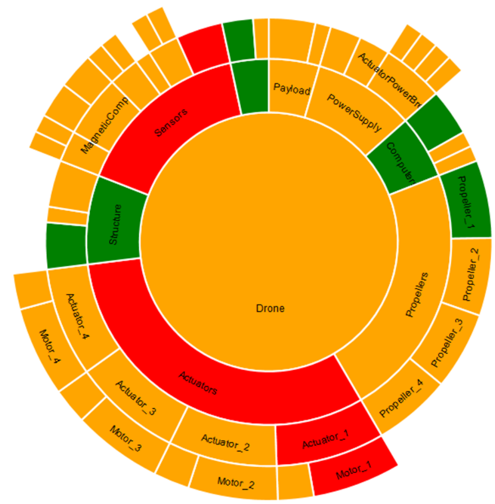

Figure 3: D3JS sunburst view for mass analysis.

4 RELATED WORK

There has been several work related to the construction of a common metamodel to address interoperability in various application domains, including space. For example, one of the CESAR project result was the definition of a common metamodel for tool interoperability in the embedded systems domain [3]. It has been continued within the CRYSTAL project that investigated tools interoperability with the use of standards such as Open Service for Lifecycle Collaboration (OSLC) [2]. Those projects focus on collaboration between domain experts inside a single company while our concern is federating SE data at the Extended Enterprise (EE) level.

The ISO standard for the Exchange of Product model data and its application protocol 233, formally ISO 10303-233 [5], is a systems engineering data exchange format. Even if a mapping of this standard with SysML has been proposed by the OMG [7], it has not been implemented by any commercial tool to the best of our knowledge. The on-going MoSSEC project issued the application protocol 243 of this standard [6] that adds the context information during the lifecycle of a project. These different Application Protocols (AP) tend to cover all the systems engineering concepts but their complexity limit its accessibility. Our approach differs from it since we try to separate the required concepts for a given analysis, as a viewpoint defined in accordance with ISO 42010 [4]. However, we actively follow the work lead by the AFNET to promote the use of this standard thanks to Interoperability Forum [1].

Once having this shared vocabulary, the way to access and use it may differ. The Open Model-Based Engineering Environment

(Open-MBEE [9]) developped by the NASA Jet Propulsion Laboratory uses a central model repository to share data. It is a an open source solution that provides communication between various models, analysis tools, and document generation tool through a REST API. The central repository solution has to duplicate all the required data for the tools that can be connected to it. It raises the concern about the single source of truth and the extra workload needed to control their access. Moreover, while a data-driven approach is a necessary entry point, the lack of services built on top of these data may lead to inconsistent uses of these data. Another NASA's initiative is OPEN-CAESAR [8] which uses a more distributed approach to address the federation of data. Our proposal is close to that as we provide bridges between heterogeneous and distributed systems engineering data. However, while data synchronization between systems domain experts (e.g., systems engineers and safety engineers) is studied, synchronization is not that obvious when data is distributed within the extended enterprise.

Still in the space domain, ESA has current initiatives to build this shared vocabulary with its Large Supplier Integrators (LSI) in the frame of the MB4SE group:

- OSMoSE: aiming at providing a system ontology for space activity, it is the cornerstone of future interoperability.
- SaSyF: aiming at architecting a digital environment for System Engineering in space industry, it provides the scope of future needs in term of interoperability.

In a long term view, interoperability tooling, such as the one we propose, should use OSMoSE ontology as a reference and at least cover SaSyF scope.

5 CONCLUSION

In this paper we have presented our proposal to integrate heterogeneous and distributed data in a multi-layered Extended Enterprise (EE) network, and to apply the methodology in a space industry context. We first recalled the challenges to be addressed in order to achieve this goal. Then, we described the use case, including the Extended Entreprise structure and the system on which the methodology is demontrated. A first viewpoint, the mass budget analysis, is being explored. As this experiment is still in progress, definitive results are not presented in this abstract but preliminary results are expected to be available at the time of the conference.

In the timeframe of the Teepee4Space project, we expect to define and explore additional viewpoints that are relevant in the space context, such as the power consumption analysis. Future works may focus on exploring aspects of the method and its implementation that have been left aside. One major topic to be explored is the integration of standardization initiatives, such as the OSMOSE initiative led by ESA or the ATLAS project led by AFNET.

REFERENCES

[1] AFNeT Services and AFIS. 2021. MBSE Related Standards and Projects. https://www.afnet.fr/Content/2021-06-0102-ASD-Programme/2021-06-01-prez-PDF/ASD2021-03-PascalHubert-m0601-08H13.pdf

[2] Beate Herbst Andrea Leitner and Roland Mathijssen. 2016. Lessons Learned from Tool Integration with OSLC. In *International Conference on Information and Software Technologies (ICIST 2016)* (Druskininkai, Lithuania), Giedre Dregvaite and Robertas Damasevicius (Eds.). Springer International Publishing, 233 Spring St, New York, NY, 10013 United States, 242–254. https://doi.org/10.1007/978-3-319-46254-7

[3] Andreas Baumgart. 2010. A Common Meta-Model for the Interoperation of Tools with Heterogeneous Data Models. In *European Conference on Modelling Foundations and Applications (ECMFA 2010) – 3rd Workshop on Model-Driven Tool & Process Integration* (Paris, France). Fraunhofer-Publica, Hansastraße 27 cD-80686 Munich, Germany), 31–39. http://publica.fraunhofer.de/eprints/urn_nbn_de_0011-n-1509586.pdf

[4] International Organization of Standardization. 2011. Systems and software engineering — Architecture description. https://www.iso.org/standard/50508.html

[5] International Organization of Standardization. 2012. Industrial automation systems and integration – Product data representation and exchange – Part 233: Application protocol: Systems engineering. https://www.iso.org/standard/55257.html

[6] International Organization of Standardization. 2018. Industrial automation systems and integration – Product data representation and exchange – Part 243: For modelling and simulation information in a collaborative systems engineering context (MoSSEC). https://www.iso.org/standard/72491.html

[7] Object Management Group. 2010. SysML and AP233 Mapping Activity. http://www.omgwiki.org/OMGSysML/doku.php?id=sysml-ap233:mapping_between_sysml_and_ap233

[8] OpenCaesar team. 2019. *OpenCaesar*. OpenCaesar community, none. http://www.opencaesar.io/

[9] OpenMBEE team. 2017. *OpenMBEE*. OpenMBEE community, none. https://www.openmbee.org/#

[10] Laurent Wouters, Stephen Creff, Emma. E. Bella, and Ali Koudri. 2017. Collaborative systems engineering: Issues challenges. In *2017 IEEE 21st International Conference on Computer Supported Cooperative Work in Design (CSCWD)*. IEEE, none, 486–491. https://doi.org/10.1109/CSCWD.2017.8066742