MGT

STATE-OF-THE-ART USER INTERACTION WITH A DIGITAL SYSTEM MODEL - EXECUTIVE SUMMARY REPORT

Project: State-of-the-Art User Interaction with a Digital System Model
Contract Number: 4000136472/21/NL/AS
Deliverable Number: ESR
Issue: 1
Revision: 5
Issue Date: 18/04/2023
Issue Status: Released
Author: Paloma Maestro Redondo
Reference: MGT-ESR
Security Marking: Public
Approved By:

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Purpose

This Executive Summary Report (ESR) is a deliverable in the frame of the State-of-the-Art User Interaction with a Digital System Model (UI DSM), and is part of the Management (MGT) package. The document summarizes the work performed during the execution of this activity.

1.2 Overview

In the framework of the “State-Of-The-Art User Interaction with a Digital System Model” activity the UI DSM web application has been designed and implemented. This solution aims to help users who are not familiar with MBSE tools and models in the review process. The architecture of the software has been carefully designed to reflect the user needs identified, and the prototype has been tested in a realistic environment.

2 APPLICABLE AND REFERENCE DOCUMENTS

The following section contain the tables of Applicable (AD) and Reference Documents (RD) used throughout this document.

2.1 Applicable & Reference Documents

Table 1: Applicable & Reference Documents

AD	Document Title	Reference
[AD1]	State-of-the-Art User Interaction With a Digital Model	AO-1-10822 RHEA Full Proposal
[AD2]	Statement of Work	ESA-TDE-TECSYE-SOW-023828
[AD3]	UI DSM web application: https://ui-dsm.mbsehub.org/login	
[AD4]	Agency Project Reviews Handbook	DG-IR/2014/317/KL (01/08/2014)
[RD1]	The Needs of non-expert Modellers in Reviewing MBSE Models: Use Case Analysis from the State-Of-The-Art User Interaction with a Digital System Model Project. SECESA 2022 proceedings.	

2.2 Terms and Abbreviations

Table 2: Definition of Terms and Abbreviations

Term	Definition
CDF	Concurrent Design Facility
Context of use	Definition of actual conditions under which a software is or will be used.
End-users	Person who ultimately uses or is intended to ultimately use a product.
ESA	European Space Agency
MBSE	Model-Based Systems Engineering
Personae	Description of a typical user profile.
UI	User Interface
UJ	User Journey
UX	User Experience

3 EXECUTIVE SUMMARY REPORT

Between January 2022 and March 2023 RHEA, together with consortium partners ATG, Human Design Group, and IRT Saint Exupéry performed work towards developing a solution to review digital system models with an improved user interface to guide non-expert users. This project can be considered the initial work in the context of improving the user experience to review MBSE models, especially for non-experts, as well as identifying and assessing user needs and pain points.

The main objectives of the activity are the following:

- To identify non-expert users' needs for interaction with a digital system model during the lifecycle of a space mission and exploit state-of-the-art technologies for the most effective interaction with the model.
- To develop and validate a prototype of a User Interaction Environment to TRL3.
- To define a roadmap for implementation of the UIE for model-based reviews at ESA, specifically in a concurrent environment.

Human Design Group was responsible for the user need analysis, the UX/UI concept, the definition of the validation plan and the preparation of the validation exercise, as well as processing the exercise results. IRT Saint Exupéry was responsible for the definition of the user requirements and the methodology consolidation. ATG and RHEA performed the state-of-the-art technology trade-off and were in charge of the development. RHEA also defined a set of use cases, was responsible for the architecture design and the elicitation of software requirements, as well as supporting the validation phase and describing the roadmap and lessons learned. Additionally, RHEA created a test model in COMET which has been used for the development, testing, and validation phases.

In the first stage of the project the team worked on the identification of user needs and pain points when interacting with MBSE tools. This was done by means of a series of interviews and surveys. We examined their needs when interacting with a digital system model during the lifecycle of a space mission. From this analysis, many pain points and needs that both expert and non-expert users of MBSE tools have mentioned and described, have been processed and classified. The main issues that users encounter when using traditional MBSE tools are shown in Figure 3. Based on these activities we then have defined several "Personae" (or types of user profiles) which allow us to project ourselves into the shoes of the end-users and keep the focus on them throughout the design phases. The personae have been merged to create an overview of the needs and pain points of the key user envisioned in this study, the non-MBSE expert with a reviewing role. With this information, the use cases were defined and the user requirements were consolidated. This work was presented for the User Needs and Requirements Review, held in March 2022, and which led to additional follow-up meetings in which the final use cases and the technology were selected.

The focus was then agreed to be the improvement of early-phase reviews and offering guidance in the review process to the users, and the selected technology was in the form of a web interface, which would present in a user-friendly format the contents of MBSE models to be reviewed. It was decided to use

COMET as modelling tool and develop a prototype which would present ECSS-E-TM-10-25 models. The four selected use cases are described below.

- Find things in Models: The UI can help the users by highlighting each domain of expertise with specific colours and displaying a legend which explain the meaning of the different modelling elements and colours. The use of a semantic browser can allow users to find the place in hierarchy of elements and show its references as a form of navigation aid.
- Presentation for Review: Users face challenges when trying to present their models directly on MBSE tools. The presentation of the model information can be enhanced by giving the user the option to compare models or check their version history. The UI can offer users different views to show their models, modelling, reviewing or presentation view, maintaining a link between both options. Customers, suppliers or reviewers can have the possibility of giving feedback directly on the tool instead of using additional documents or emails, which is useful for saving time, and all users can add notes or comments to the models. In this way, all the ideas, model related information and comments are kept in the same tool.
- Review Budgets: After budgets have been created, users can only check the calculations made to obtain them by looking at the codes which generate the reports. Users can benefit from a UI option to extract these calculations from the reports and display them in a user-friendly manner (for non-programming experts). Saving the budget calculations can help users to access this information anytime, even for previous budget versions. By implementing an option to also export the budget calculations as a report or to a file, experts or other interested stakeholders could check them to ensure that everything has been done properly and that no errors exist in the budgets.
- Discussion support: The collaboration between different MBSE tool users is not guaranteed. To achieve a good understanding and consistency of models, the communication through models must be imposed. For this commenting and feedback mechanisms must be implemented.

The team then focused on the definition of the architecture design, and the derivation of the software requirements. The initial mock-ups for the web application were also created. This was presented at the Technical Specification Review in July 2022, and concluded with a workshop organised to discuss and agree on the viewpoints of the web application, the user journeys, and the UI design. The viewpoints were then connected to the review objectives and for each review objectives a task-decomposition was made.

In the next stage, the team proceeded with the development of the web application. The backend and frontend were developed as defined in the previous phase. A COMET engineering model was also created to support the development. The guidance and structure of the web application were discussed with expert reviewers to ensure full consistency with the review process and with the Agency Project Reviews Handbook [RD4].

The development was performed in an agile-like manner, and the developers received continuous feedback from all stakeholders by means of iterative internal meetings and bi-weekly meetings with the Agency. The web application was released periodically to allow the Agency and other consortium partners

to experience the progress and gather feedback. This phase concluded with the Application Review in February 2023.

The web application developed contained the following key elements presented in Figure 1:

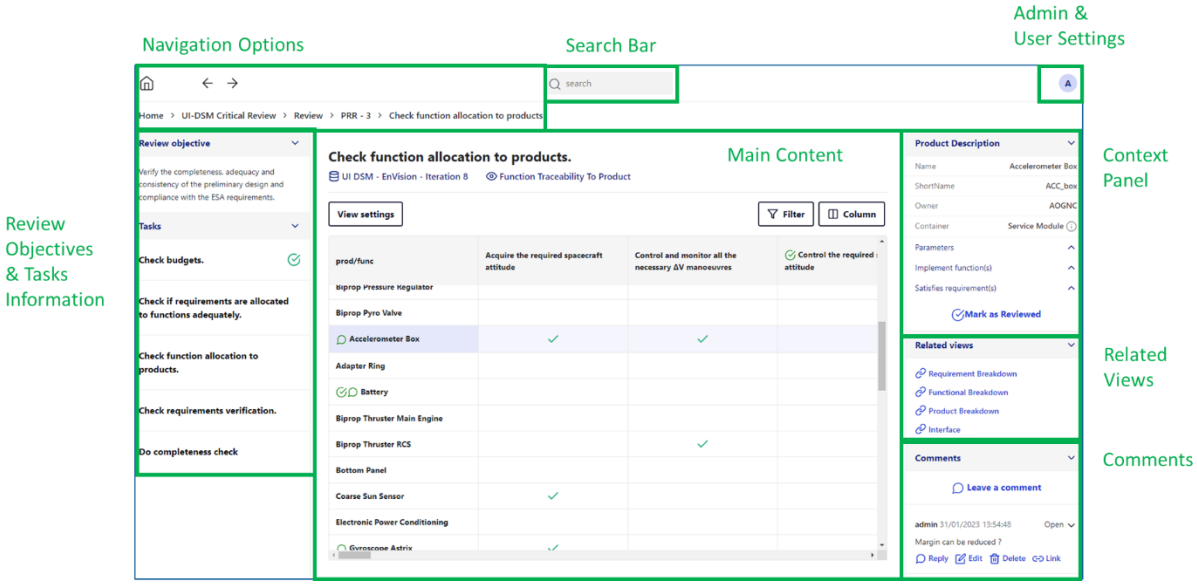

Figure 1: UI DSM web application main structure

From the left hand side, the user can find the assigned review objective and associated tasks. Each task has one or more associated views, with one of them as a designated starting point. In the view the reviewer can execute the reviewing tasks, finding and filtering information. For each aspect of the model, context information is provided in the context panel. Also, related views are presented, where the element can be inspected in a different view. The user can find issues in the model and report these as comments. Finally he/she can mark a review task as done. The right upper corner allows the user to navigate though projects and user settings, as well as access the admin functionalities. In the top centre a separate search function enables the user to find things that cannot be found in the present view and finally, the prototype has basic review management and user administration functions.

Although there are many different views, there are 5 archetypical viewpoints shown in Figure 2:

- Breakdown
- Traceability Matrix
- Interface and Physical Architecture Diagram
- Budget
- Context

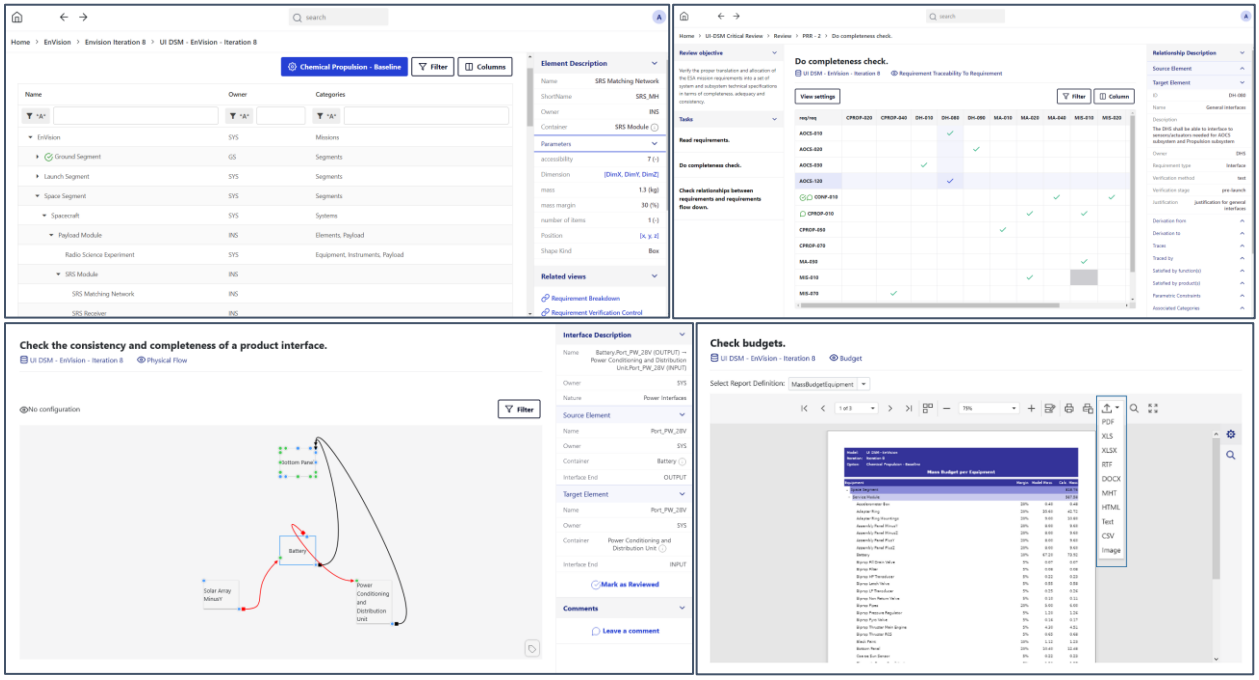

Figure 2: Examples of all archetypical viewpoints. Top left: breakdown view, top right: traceability view, bottom left: architecture diagram, botoom right: budget view.

The final tasks of the project consisted on the organisation of a validation exercise that took place at ESA CDF. This was used to evaluate the developed web application and the user interaction in a realistic environment. A concurrent review exercise was performed with a group of users as part of this validation plan, and individual interviews were also performed to obtain a more detailed analysis of the tool usability. The results of this activity have been presented in the Final Review in March 2023.

Among the results of this exercise, the team has assessed whether the mains issues with traditional MBSE tools identified in the first phase of this project had been sufficiently addressed. The bar chart in Figure 3 shows the proportions of participants for whom the issues remain with the UI-DSM-APP. Users identified key improvements related to issues typically found when using traditional MBSE tools, being the most important that users find now in the UI DSM app the interface layout less clustered and the data models easier to understand.

The team also gathered feedback on the collaborative side of the application. It can be concluded that most participants find it is a relevant tool. The graph in Figure 4 shows the percentage of participants who find the tool relevant to conduct concurrent reviews.

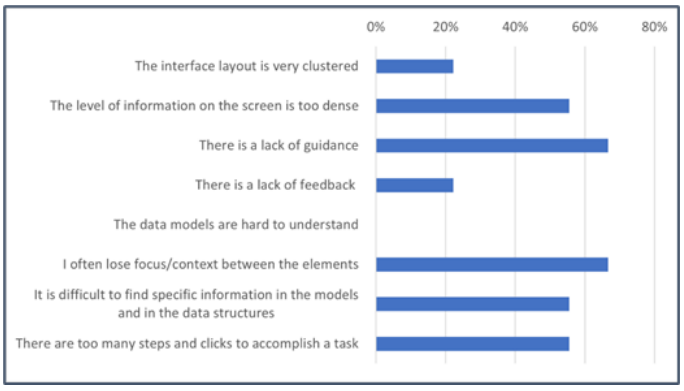

Figure 3: Proportions of participants for whom each main issue remains with the UI-DSM-APP.

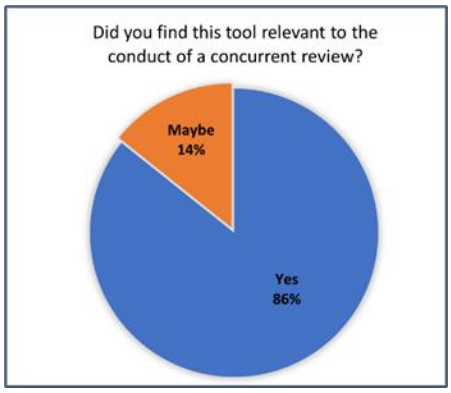

Figure 4: Participants' answers on the UI-DSM app relevancy for concurrent reviews.

The proposed roadmap for implementation of the UI DSM web application for model-based reviews at ESA, specifically in a concurrent environment, is presented in Figure 5 in a graphical format. It shows the main overall tasks for a follow-up activity. To be highlighted the coverage of reviews corresponding to other mission phases, not just the initial phase reviews, the ability to interpret data from models coming from domain specific tools, and the interoperability with the MBSE Hub and the Space System Ontology, instead of just displaying COMET models. The project team would also plan training sessions for the review managers and training material that could be directly included in the solution.

	Task Mode	Task Name	Start	Finish
1		**Identification of new use cases and user needs**	**Thu 01/06/23**	**Mon 28/08/23**
2		Assessment of User needs for other mission phases	Thu 01/06/23	Fri 14/07/23
3		Evaluate and select potential domain specific tools to extract information from for reviews	Thu 01/06/23	Fri 14/07/23
4		Identify data sources and gather example data	Tue 27/06/23	Tue 01/08/23
5		Define new use cases	Wed 02/08/23	Fri 18/08/23
6		Identify specific features missing in first prototype	Mon 21/08/23	Mon 28/08/23
7		**Tool selection and architecture design**	**Tue 29/08/23**	**Tue 31/10/23**
8		Explore and select new state-of-the-art solutions	Tue 29/08/23	Fri 29/09/23
9		Architecture design	Mon 02/10/23	Mon 16/10/23
10		Consolidate UI/UX design	Mon 02/10/23	Mon 23/10/23
11		Defintion of Requirements	Mon 16/10/23	Tue 31/10/23
12		**Development**	**Wed 01/11/23**	**Mon 29/04/24**
13		Development of the new tool	Wed 01/11/23	Mon 29/04/24
14		Creation of additional MBSE models to support development and testing	Mon 18/12/23	Wed 31/01/24
15		Creation of documenttion and tutorials	Mon 01/04/24	Mon 29/04/24
16		**Evaluation**	**Tue 30/04/24**	**Fri 21/06/24**
17		Prepare Evaluation	Tue 30/04/24	Fri 10/05/24
18		Individual Evaluation exercise	Mon 13/05/24	Fri 17/05/24
19		Concurrent Evaluation exercise	Mon 20/05/24	Fri 24/05/24
20		Process Evaluation Results and Determine needed updates	Mon 27/05/24	Fri 21/06/24
21		**Updates and concludsion**	**Mon 24/06/24**	**Fri 30/08/24**
22		Perform required software updates	Mon 24/06/24	Mon 22/07/24
23		Training of review managers	Tue 23/07/24	Fri 30/08/24
24		Deployment	Tue 23/07/24	Fri 30/08/24

Figure 5: Proposed roadmap (Gantt chart)

The work performed during this activity has been presented at the SECESA Conference 2022[RD1].

Overall, the consortium worked very well together on all levels, communicating constantly, and providing development support when it was necessary.

4 CONCLUSIONS

The tasks of this activity has led to the following concrete results:

- Development of a web application to support the performance of reviews in the context of MBSE digital models.
- Experience in implementing different types of viewpoints to support the review of MBSE models
- Experience in assessing the needs of the different project phases and reviews, and defining the way in which information needs to be presented to the reviewers
- Complete analysis of user needs, and deep assessment of state-of-the-art available technologies
- Results of the validation exercise which also covered the concurrent aspect of the reviews

The UI DSM web application can be accessed in this link: https://ui-dsm.mbsehub.org/login.

The source code, license information, and other additional files can be found on RHEA's GitHub: https://github.com/RHEAGROUP/UI-DSM.

The following conclusions can be drawn from the project:

1. Indeed a web enabled application is capable of offering MBSE users guidance and helps them to find things in models, even if they haven't been involved in the modelling effort themselves.
2. In light of point 1, we also see indications of the reverse effect; expert MBSE users/modellers find the guidance unpractical and would like to navigate the model without restriction.
3. Creating a highly interlinked model, which is required to support effective navigation though the model, takes more modelling effort. The model needs to be consistently linked and all elements need detailed and consistent classification. While such consistency has more purposes in the light of MBSE and model integration, this level of interrelatedness is not currently custom for PRR or SRR. In the project we had to enhance the model for it to show results in e.g. traceability matrices. This extensive classification and consistency had to be added to the model for the purpose of various functions in the application, as it was not included in the models that were available to us. This could imply that the amount of rigour in the model exceeds the current practice. A balance between rigour and relevance is therefore critical in this aspect, as it is easy to 'over structure' the model for the sake of navigability.
4. To support (collaborative) reviewing, review management and enhanced collaboration features are an important additional feature. The current prototype only had basic functionalities for this such as assigning reviewing tasks, marking them as done and commenting on the model. To further support this aspect, many future work suggestions have been made.
5. Users search for visualisation of the model, diagramming, but creating intuitive diagrams of a system is – so it seems – still an art and not yet an analytic effort that can be easily automated, besides the technical challenge in this (auto-layout), good models also require abstraction of the model to selectively display key aspects, which is difficult to automate and may not be solved by simple filtering or automatic selection of elements and relations. Such automation would require complex ontology embedded in the model.

Future work has been suggested in high levels of detail and roughly focuses on several key aspects:

- Enhancing review management features, to coordinated a team of reviewers various features could support the overview of progress both in reviewing and in tracking the implementation of revisions.
- Further improving the navigation of the model, for which specific alternatives have been proposed. The tool would need to also show clearly an overview of the review objectives, tasks and all viewpoints which can be shown in the application. For this point two of the conclusions needs to be encountered, creating a navigation that supports both novice reviewer as well as MBSE experts.
- Enhancing diagramming, as stated above, users feel the need for visualisation, but it is challenging to create such visualisation not only from a technical point of view, but also in abstracting the information to balance the complexity and the explanatory effect of a visualization.
- Enhancing flexibility, enabling both expert MBSE users as well as the currently focused non-expert MBSE users to work in the same tool, offering guidance without creating restrictions.
- Lifecycle support, the prototype is connected to a live COMET server, a future solution would need to be connected to the MBSE Hub and would need to be able to trace feedback throughout the lifecycle of the model.
- Improvement of the search function currently allows to find data and views in the model, but it should be improved to show the results in a more structured way.
- A final additional feature for the tool which could support the review is the 3D representation of spacecraft/mission.