

# SYSTEMS ENGINEERING FROM A WEB BROWSER: TURNING MBSE INTO INDUSTRIAL REALITY

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## ABSTRACT

This paper presents a novel, web-based systems engineering collaboration tool called Valispace, which is customized to the current and future needs of the space industry. Increased project complexity, with an increasing number of teams participating in a single project, demands for more efficient inter-team and interdisciplinary collaboration. The practice of Model Based Systems Engineering (MBSE) is already being adopted throughout the industry, but even with a well defined systems engineering approach there are few collaboration tools that are in wide use. In this paper a study of the design and collaboration tools currently used throughout the industry is presented. The perceived problems with the current tools and possible improvements are investigated. The conclusions from the study are used to validate the development of a new engineering tool.

## INTRODUCTION

Traditionally, in the systems engineering process, the outcome of each stage is a set of documents describing the output of the activity at that level. These documents then serve as the input for the next stage in the systems definition process. This is described in [1] as a document-centric approach. The documents that are the result of an activity are often further modified so that the traceability to the original models are lost. Advances in information technology have enabled documents to be digitalized rather than in paper form, but this does not solve the problems of inconsistencies in the documentation. Model Based Systems Engineering (MBSE) is an emerging branch that aims to overcome the problems of the document-based approach by defining a model-based approach, which makes use of modelling to analyse and document key aspects of the systems engineering lifecycle. Many companies are already switching to an MBSE approach for systems engineering, but it is not yet widely adopted by the industry. While MBSE solves many problems, it has not taken further advantage of how current information technology could make the systems engineering tools smarter [2]. Smarter tools that manage the project data in an efficient way without losing traceability could save companies huge amounts of time and money.

In the following sections a proposed new engineering tool, developed using modern information technology techniques, is presented and discussed. At first, the current industry status is presented based on the results of a short study conducted. After that, the reason why MBSE is not yet widely adopted by the industry is examined. Thereafter comes a description of the proposed engineering tool, Valispace. Finally, a strategy to bring the proposed tool to the industry and make it a standard for systems engineering is outlined.

## INDUSTRY STATUS

To evaluate the need for a new engineering tool, the current status of systems engineering tools in the industry was investigated. A short survey was conducted to get some indications of the current needs of the industry. The survey was sent to engineers in the aerospace industry as well as related industries. It included questions about the tools currently used in the respondent's company and perceptions of how the project data is managed in the company. The full questionnaire can be seen in Appendix A.

In total there were 36 respondents to the survey. The first questions served to categorise the respondents according to size of company, position in company, industry and country. A majority of the respondents were systems engineers (33.3%) and a majority worked in the space and astronautics industry (38.9%).

The next questions focused on the kind of tools used by the respondent in their daily work. The most used tools can be seen in Fig. 1. As expected the most used data management tools were found to be Excel, Word and PowerPoint. The most used simulation and calculations tools included Excel, Matlab and Simulink. For modeling and design many different tools are used with few of the respondents using the same tools. A majority stated that no modeling and design tools are used, indicating that many respondents are not working directly with CAD and/or PCB design. Furthermore, it is interesting to point out that a majority of the respondents do not use any requirements tracking tool in their project.

Respondents were asked to identify problems with the current engineering tools in a free text answer. The answers included inconsistencies in documentation, scattered information between many different tools and documents, lack of flexibility and lack of automation. Another problem stated was that the project data cannot easily be accessed by all stakeholders which compromises the flow of information. Unfriendly user interfaces was also pointed out as a drawback of several tools and it was stated that many clicks are needed to get to the objective. Many times, presenting the results of the engineering work is cumbersome and more time-consuming than actually producing them. There are lots of different tools that need to work together and the tools are not easily customisable to specific needs.

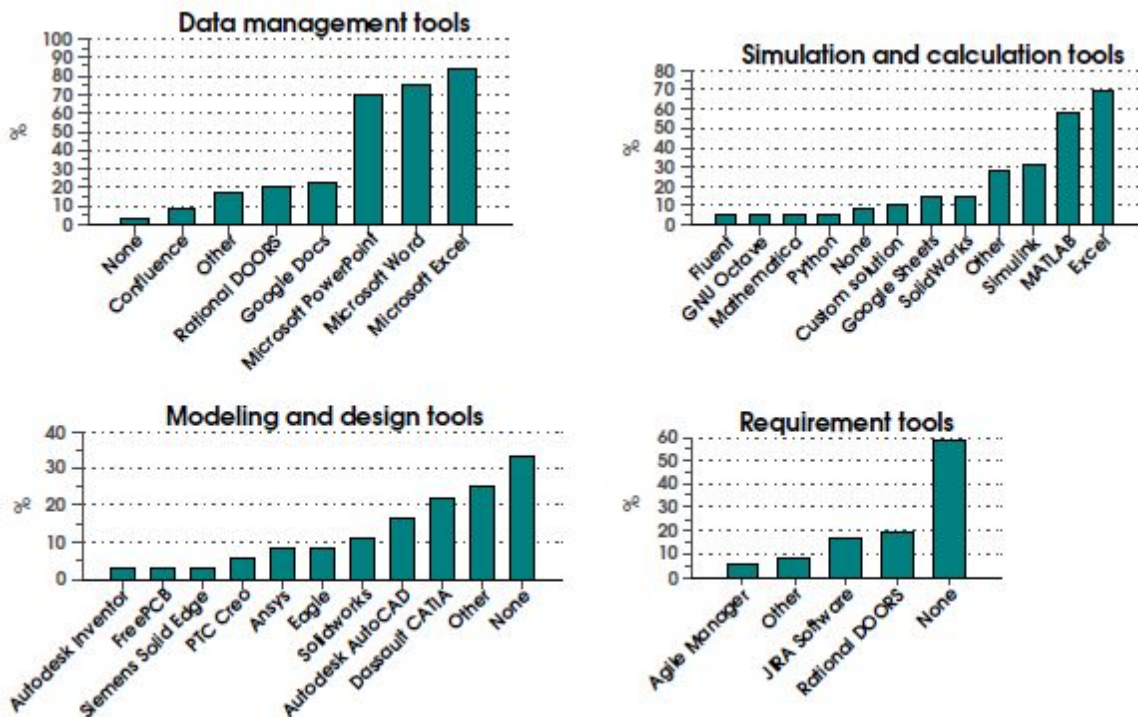


Fig. 1. Distribution of the engineering tools used among the respondents of the survey

The survey also included rating eight statements from 0 to 10, where 10 means that the respondent fully agreed with the statement and 0 means that the respondent fully disagreed with the statement. The statements can be seen in Table 1. The mean value of the respondents ratings together with the standard error of the mean can be seen in Fig. 2. In the first four statements, a high rating reflected problems in the systems engineering process (I often find inconsistencies, there are often misunderstandings etc.), while in the last four statements a high rating reflected a positive attribute (it is easy to find the data I need, the data is well organised etc.). It is seen that the mean of the first four statements were higher than the last four statements. The statement with the highest rating was “I often copy-paste data between the different tools I use (e.g. emails, Excel, Word, MATLAB)” and the statement with the lowest rating was “In my current project it is easy to get an overview of the product development”, which indicates that these are two of the biggest problems faced. However, there is a large variance in the response data, which indicates that the answer to the questions are project dependent, with some respondents being very satisfied with the project organisation and others not. An interesting result can be seen in Fig. 3, where the rating of the statements were analysed depending on which position in the company the respondent had. Of the respondents there were 3 persons with a CEO position and 12 with a systems engineering position. It is seen that the mean of the CEO ratings are lower for the first four statements and higher for the last four statements, indicating more satisfaction with the engineering tools. The result is not conclusive due to the small number of respondents in each category, but it is interesting to reflect on the numbers, as it is the system engineer who in general works more closely with the engineering data and tools.

To the question whether the respondents thought their engineering work could be more efficient, 97.2% answered yes. Furthermore, 100% answered yes to the question if they are willing to try a new engineering tool if it saves time and money. The features that would be most important in a new engineering tool were concluded to be “use friendly”, “automatic change notifications” and “version control”, Fig. 4.

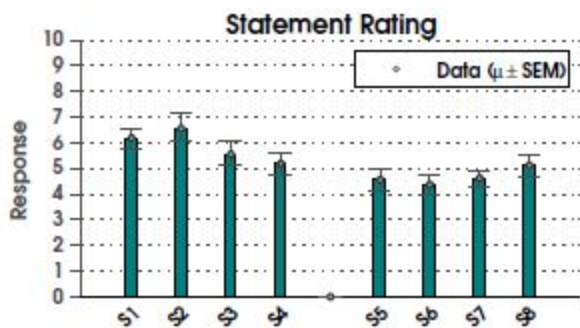


Fig. 2. Mean and standard error of the mean of the statement ratings

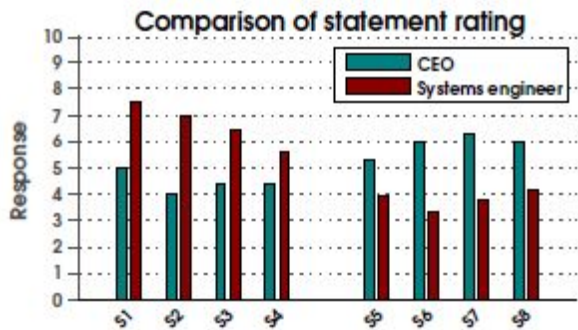


Fig. 3. Comparison between ratings of respondents with position CEO and Systems engineer

Table 1. Statements rated by respondents according to how much they agreed with the statement.

<b>Statement 1 (S1)</b>	In my current project I often see inconsistencies in the documentation.
<b>Statement 2 (S2)</b>	I often copy-paste data between the different tools I use (e.g. emails, Excel, Word, MATLAB).
<b>Statement 3 (S3)</b>	I spend much of my time writing engineering reports and documentation.
<b>Statement 4 (S4)</b>	In our team there are often misunderstandings about what the current technical baseline is.
<b>Statement 5 (S5)</b>	I always receive a notification about a change in the project data.
<b>Statement 6 (S6)</b>	In my current project it is easy to get an overview of the product development.
<b>Statement 7 (S7)</b>	In my current project it is easy to find data that I need for calculations or presentations.
<b>Statement 8 (S8)</b>	In my current project the project data is well organised.

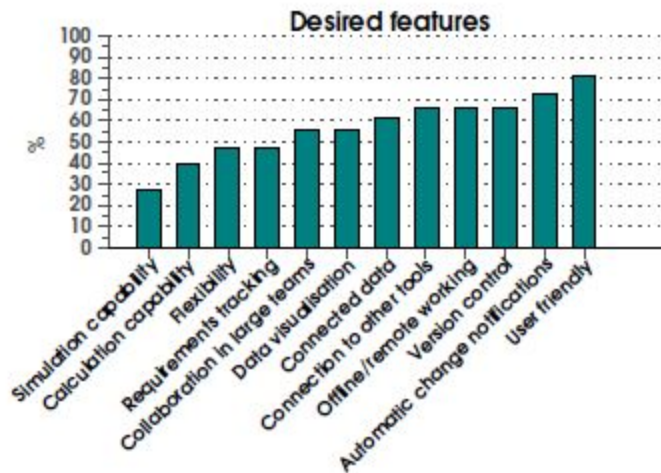


Fig. 4. The desired features of a new engineering tool in % of respondents wanting a certain feature

To summarize the current needs of the industry, we believe that a new engineering tool has to

- Be user-friendly and intuitive, and make sure that the engineer does not have to learn complicated interfaces or programming languages
- Take care of communicating changes in the project data automatically
- Keep track of different versions of the project data so that nothing is lost when changes are made
- Have interfaces to other tools to avoid copy-pasting which can lead to inconsistencies

#### WHY IS MBSE NOT WIDELY ADOPTED BY THE INDUSTRY?

The goals of MBSE are to improve communications, improve quality of system design, increase productivity, and reduce risk [3]. Even though MBSE is an emerging practice in industry there are not many MBSE methodologies that have dedicated tools to support the activity [4]. Also, the MBSE tools that exist are often designed to be used with a certain MBSE methodology. From the perspective of the user, the best tool would be one that does not impose a specific methodology for the systems engineering process. In fact, it would not oblige the systems engineer to learn a specific methodology nor modeling language to be able to use the tool. Based on our research and results from the study we have identified three major reasons which hinder MBSE practices to spread throughout industry:

- Effective MBSE requires time and effort spent on training the project team and the company has to already have a mature systems engineering process
- It is required to understand the model and modeling language, which creates a barrier for some stakeholders that are not necessarily systems engineers
- MBSE tools are not flexible enough and are often designed for a specific MBSE methodology

Large companies are in general adverse to change and are often reluctant to modify their processes. Since MBSE practices takes time and effort to become truly helpful to the company many are not keen on switching at first. Current complicated and inflexible tools do not provide an easy transition to MBSE. Once an MBSE practice is established, the often abstract model can seem confusing to stakeholders that are not directly involved in creating the model. Being forced to understand a specific modeling language can create barriers and make communication more difficult.

## PROPOSED ENGINEERING TOOL

The findings from the study of current engineering tools and the identified problems that prevent MBSE from being adopted by the industry have been used to validate the development of a new engineering tool. Valispace is a web-based platform in which engineers create a logical model of the product they are developing. All technical properties are stored in one consistent database with formulas connecting these properties. The connection between properties sets the proposed tool apart from current document-based solutions, as it ensures rapid visualisation of parameter dependencies and clear views on how design changes affect the whole system. The tool allows all engineers in a project, even across company borders, to work simultaneously with consistent project data. Data can be exchanged with suppliers and customers from within the tool, which helps the user maintain an overview of the complex system and reduce development time. The single database provides consistency throughout all project phases and allows for reuse of design information between projects. A version control system is employed to easily be able to iterate on solutions while still keeping track of the project data history. Automated interfaces with specialized engineering tools limit the possibilities for error and allow to track dependencies also outside of the tool itself.

As a browser-based tool, Valispace is platform independent. It is easy to set up and can be accessed on any computer, mobile phone or tablet with a web browser, allowing for more flexibility. Modern web application standards are applied for a smooth user experience. The flexible and extendable interface allows all project team members to get customisable live views and editing options for the product data. The advantages of the proposed tool are summarized below.

*Easy to use.* The proposed tool requires minimal training to use as it has a simple web interface design, which most users are familiar with and use every day on the internet. The software is intuitive and the workflow is natural. The time and effort spent on training the project team, one of the drawbacks of current MBSE tools, is very little due to the fast learning curve. The user does not have to learn the underlying model before starting to design the product and can learn about the functionality of the tool as the model grows more complex.

*Consistency.* A consistent database is the foundation of the tool. Detecting inconsistencies in the late phases of a project costs enormous amount of time, money and re-work.

*Flexibility.* As a browser based tool, it does not need a specific platform to run. The systems engineer can access the data from anywhere with any device with support for a web browser. It is also flexible in the meaning that new features can be easily added as future challenges of systems engineering emerge.

*Easy access to data.* The flexible web interface also allows for different views for different stakeholders. It is not required to understand a certain MBSE methodology and/or modeling language to get important information about the system.

*Notifications.* As changes propagate through the system, it is communicated directly to the appropriate engineers through an automatic notification system. The user always gets informed about a change in the project data and can take appropriate actions.

*Connection to other tools.* The data in the database can be accessed from external tools which makes it very flexible. Data can be exported and imported in standard formats or accessed directly from other tools through dedicated plugins.

## **BRINGING MBSE TO THE INDUSTRY**

The Valispace engineering tool has recently been released to the general public as an SaaS (software as a service) product. The tool is currently being used in a pilot project at OHB System in Bremen, Germany, where it is used in the early phase of a satellite project. Furthermore, two smaller businesses are in the process of signing a contract to use Valispace in their hardware development projects. The tool is provided as a service with a monthly subscription fee. It is either installed on the customer premises or distributed as a cloud version. The limited cloud version assures that also small companies with limited resources can benefit from the tool.

The problems of MBSE tools mentioned in the previous sections can be overcome by a smart engineering tool that displays connected data in a flexible user interface. We believe that the proposed engineering tool is a solution to make model based engineering widespread throughout the space industry.

## **CONCLUSION**

Within the space industry in general, systems engineering work is still largely document-based. This approach leads to inconsistencies in the engineering data and wastes many engineering hours on document management. In this article a new, web-based engineering tool was described. A study was conducted to investigate the problems with current tools used in industry and served as a justification for the development of a better engineering tool. It was found that problems with inconsistencies in the engineering data and inefficient data management as well as difficulties with getting an overview of the project data contribute to the inefficiency of systems engineering work. MBSE tools, currently not widely adopted by the industry due to their complexity and inflexibility, can be made more efficient. The proposed solution enables all engineers to collaborate on complex projects in a web-based software environment and ensures consistent data throughout the whole project.

Further studies will be made after the tool is brought to market to evaluate the benefits to the industry.

## **REFERENCES**

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- [2] J. Kasser, "Model-Based Systems Engineering: Back to the future?", *Asia-Pacific Council on Systems Engineering (APCOSE) Conference*, Yokohama, 2013
- [3] INCOSE UK, Model Based Systems Engineering Leaflet, "Why do MBSE?", Issue 1.0 January 2012
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## **APPENDIX A**

### **Survey on Model Based Systems Engineering**

Answer alternatives are given in brackets after the questions.

1. What type of company do you work for? (Large corporation, Small/medium business, Startup, University, Other)
2. What position do you have in your company? (Associate engineer, C-level executive, CEO, Chief Engineer, Consultant, Intern, Junior engineer, Project manager, Senior engineer, Specialist, Systems engineer, Other)

3. What industry do you work in? (Aeronautics, Agriculture & Farming, Automotive, Chemical plants, Defense & Security, Drones and UAVs, Consulting, Electronics, Energy, Finance, Healthcare, Insurance, Manufacturing, Research, Road construction, Space and astronautics, Submarine, Sustainability & Environmental, Other)
4. Which country do you work in?
5. Do you use any Model Based Systems Engineering practices at work? (Yes, No, Sorry I don't know what Model Based Systems Engineering is)
6. What simulation and calculation tools do you use at work? (COMSOL, Excel, Fluent, GNU Octave, Google Sheets, MAGIC Tool Suite, Maple, Mathematica, MATLAB, Simulink, SolidWorks, None, Other)
7. What modeling and design tools do you use at work? (Ansys, Autodesk, AutoCAD, Autodesk Inventor, Dassault CATIA, FreeCAD, FreePCB, Siemens Solid Edge, Solidworks, TactonWorks, None, Other)
8. What data management tools do you use at work? (Confluence, Google Docs, Microsoft Excel, Microsoft PowerPoint, Microsoft Word, Rational DOORS, None, Other)
9. What document management systems/tools do you use at work? (Apache Subversion, Arena PLM, Autodesk Fusion, Confluence, Dropbox, GitHub, Google Drive, SAP PLM, Sapienza Eclipse, Siemens Teamcenter, None, Other)
10. What requirements tracking tools do you use at work? (Agile Manager, Blueprint, Jama Software, JIRA Software, Rational DOORS, TraceCloud, Visure Requirements, None, Other)
11. What communication and collaboration tools do you use at work? (Dropbox, Email, Fax, Google Drive, Hipchat, Phone, Slack, Skype, Trello, None, Other)
12. How much do you agree with the following statement? (0-10)  
In my current project I often see inconsistencies in the documentation.
13. How much do you agree with the following statement? (0-10)  
I often copy-paste data between the different tools I use (e.g. emails, Excel, Word, MATLAB)
14. How much do you agree with the following statement? (0-10)  
I spend much of my time writing engineering reports and documentation.
15. How much do you agree with the following statement? (0-10)  
In our team there are often misunderstandings about what the current technical baseline is.
16. How much do you agree with the following statement? (0-10)  
I always receive a notification about a change in the project data.
17. How much do you agree with the following statement? (0-10)  
In my current project it is easy to get an overview of the product development.
18. How much do you agree with the following statement? (0-10)  
In my current project it is easy to find data that I need for calculations or presentations.

19. How much do you agree with the following statement? (0-10)

In my current project the project data is well organised.

20. What problems do you have with the tools you use at work?

21. Do you think your engineering work could be made more efficient? (Yes, No)

22. Would you be willing to try a new engineering tool if it saves you time and money? (Yes, No)

23. If yes, what features would you like to see in a new engineering tool? (Automatic change notifications, Calculation capability, Collaboration in large teams, Connected data, Connection to other tools, Data visualisation, Flexibility, Offline/Remote working, Requirements tracking, Simulation capability, User friendly, Version control, Other)