DATA-DRIVEN SYSTEMS ENGINEERING: TURNING MBSE INTO INDUSTRIAL REALITY

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ABSTRACT

This paper expands upon a paper presented at the SECESA in Madrid 2016 [1]. It explored the reasons, why companies in the space industry that are in the process of moving from a document-based systems engineering approach to Model Based Systems Engineering (MBSE), don't yet widely adopt existing MBSE solutions, due to their complexity and inflexibility. The proposed solution to the lack of adoption presented a browser-based, collaborative engineering tool which ensures consistent data throughout the whole project lifecycle. This paper expands on that assumption and presents the concept of a new data-driven systems engineering approach to spread the use of MBSE in the industry.

1. INDUSTRIAL REALITY

Most companies in the space industry still use a document-driven approach to engineering. In traditional systems engineering, the outcome of each design stage is a set of documents describing the output of the activity. These documents then serve as the input for the next stage in the development process. The documents are then often further modified to increase the degree of detailed design in the engineered product, adding more dependencies and technical changes, which lead to document inconsistencies. Advances in information technology have enabled documents to be digitalized rather than stored and managed in paper form, but document management does not solve the problems of inconsistencies within the documentation. Datapacks[1] can contain hundreds of documents, referencing many kinds of analysis. Consistency amongst these documents and underlying analysis is today only ensured by hand, since the contents of these documents are prepared in most cases with Microsoft Office and reference data only by copy-pasting. Document inconsistencies today are a main contributor to major project delays and budget overruns and sometimes even lead to catastrophic failures[2].

2. DATA-DRIVEN SYSTEMS ENGINEERING

Good data management is becoming more and more essential for engineering companies in the space industry. When data is sufficiently managed, documents just provide a snapshot perspective on that consistent data model. Data-Driven Systems Engineering (DDSE) is a novel method, which enables a wider spread of MBSE throughout the industry and allows for consistency of documentation:

1.1 Definition

Data-driven refers to an approach where engineering data and associated structure, links and connections constitute the foundation of the systems engineering process.

1.2 Identified problems

Firstly, one of the reasons that MBSE is not yet widely adopted by the industry is that, while it provides good representation form of models, it quickly becomes too complex and inflexible for practical use. As presented in [1], MBSE often requires much time and effort spent on training and additionally, the company has to already have a mature systems engineering process. Furthermore, it is required to understand the model and modeling language, which creates a barrier for many stakeholders in the project.

Secondly, as stated in [2], "MBSE methodologies place so much emphasis on the representation form of models and overlook the importance of the underlying data for the verification and analysis of models, which may easily lead to some serious problems, such as the data inconsistency and duplicate definition.". This hold true as long as the data is not connected. Systems can be modeled in much detail, however, when any

[1] Contracts by space agencies usually define a set of documents as main deliverables, bundled into multiple datapacks during different stages of the development process of space products.

[2] Probably the most famous example in the history of space exploration was the inconsistency between metric and imperial units which lead to the total loss of the Mars Climate Orbiter in 1999.

engineering value is changed its effect on the system as a whole is not propagated, meaning that inconsistencies in the underlying assumptions are present.
This is why MBSE is today mostly used in early stage phases of space product development, but not as a living tool throughout the lifecycle phases.

1.3 Benefits of DDSE

The following sections summarize the identified benefits of using a DDSE approach.

1.3.1 Consistent database of connected engineering values

A consistent database should be the foundation of the systems engineering approach and is the core of DDSE. With a consistent database of up-to-date values, metadata (such as units), correct assumptions and analyses can be made at early stages of a project. Detecting inconsistencies in the late phases of a project costs enormous amount of time, money and re-work. Engineering values need to be connected to each other through formulas or simulations to enable automatic propagation that allows for continuous consistency throughout the complete development lifecycle.

1.3.2 Automation

Automating all kinds of manual operations through scripts and macros helps to increase efficiency drastically, and reduces the possibility for errors. Therefore an open and clearly documented Application Programming Interfaces (APIs) that allows for tool interaction is more important than the inner model of the MBSE tool.

1.3.3 Traceability and transparency

Only by being natively multi-user capable and providing clear interconnections between data and users, it is possible for the models to become living data, which is continuously maintained and re-used. Traceability allows for every member of a project team to recognize at any point in time, which value has been derived in which way.

1.3.4 Optimization

Once connected data is stored in such a system and linked with clear relationships, optimizer tools can be implemented to make use of the modelled relationships and automatically help the engineer derive optimized versions of her design. This way MBSE becomes more than a documentation/visualization tool, but rather an additional tool for the engineer to arrive at sound solutions.

3. PRACTICAL IMPLEMENTATION

In the following sections, a practical guide to the necessary steps to implement DDSE is presented.

3.1 Infrastructure

To implement Data-driven Systems Engineering, it is necessary to start by creating an infrastructure that enables easy instrumentation and data access for all stakeholders. Data collection and storage can be seen as the bottom of an engineering data pyramid, as shown in Fig. 1. This 'hierarchy of needs' is inspired by [3] and just as in Maslow's pyramid of needs, where food and shelter are needed before self-actualization, in the engineering data pyramid a basic unified data storage and a certain data structure are needed before it is possible to perform advanced data analytics, apply optimization algorithms and machine learning.

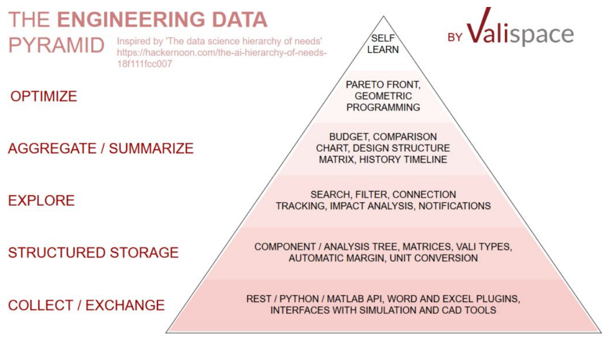

Figure 1. The engineering data pyramid.

The basis of DDSE must therefore be data collection into a single database, available concurrently to all engineers collaborating on a certain product or project. Adding structure to that data is one step above in the pyramid. To allow for clear communication and analysis, values are structured using a simple data model. The relations to other values are also stored, for example through formulas. Keeping the data structure simple allows for easier collaboration and better transparency. This structure allows for advanced ways of exploring engineering data and its connections, improving the efficiency of daily work and creating new insights. The levels at the top of the pyramid can build on the layers of data collection and structure, and therefore allow for advanced exploration, powerful data analytics and automations.

3.3 Tool connections

To be truly data-driven, it is important to connect tools and systems from different disciplines and areas through open APIs. Without horizontal interfaces and connections the hardware design becomes a collection of island solutions which does not represent a true view of the data. As explained in [4], during the design phases of a space project, the exchange of data between different engineering tasks and their corresponding tools is key to ensure consistency in the final design. Fig. 3 shows the interactions between engineering task which is needed to ensure a consistent design.

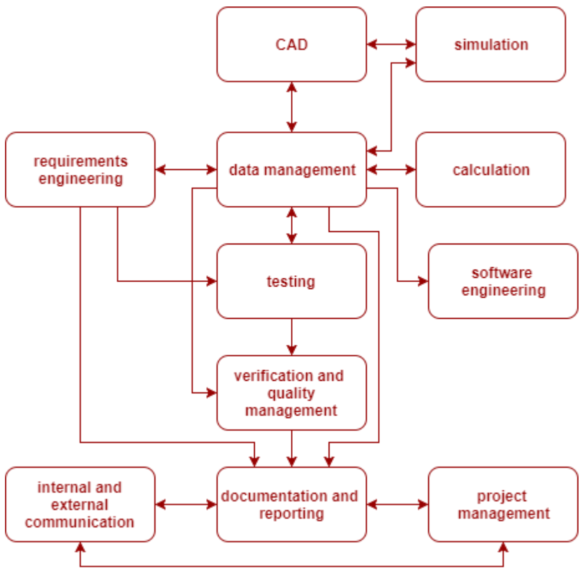

Figure 2. Interactions between engineering tasks in the design phase [4].

To set up an efficient work flow based on these interactions, a set of modern, web-based tools with the needed functionalities and data exchange capabilities are necessary. Examples of such tools are collaborative browser-based 3D software (OnShape), requirements software (Jama Software), Kanban tracking tools (Trello), concurrent engineering data management systems (Valispace), and chat-based communication channels (Slack). With standardized APIs, data exchange between these tools becomes trivial. Data should be exchanged automatically between as many tools in the engineering tool chain as possible, feeding in and reading it out again and replacing manual error-prone copy pasting work.

This is the basic set-up to create a single source of 'truth' with the latest, up to date values.

4. CONCLUSION

In conclusion, the Data-Driven Systems Engineering (DDSE) approach is a proposed solution to the low industrial adoption of MBSE throughout the past decades with the aim to enable model based engineering on a practical level through the engineering lifecycle. Implementations of this approach in the form of collaborative tools (such as Valispace) will have to prove that they will facilitate turning MBSE into industrial reality by ensuring that connected data is a central part of the engineering process and empowering engineers to collaboratively develop complex products.

5. REFERENCES

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