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Concurrent Design and the transition to adoption of MBSE at the Dutch MOD

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INTRODUCTION

Concurrent Design has been successfully introduced and applied at the Dutch Ministry of Defence [1]. In a three year pilot phase the team has successfully laid a foundation for implementation of the Concurrent Design approach, supporting over 30 teams to speed up their procurement task with increased rigor and effective collaboration. In support of that mission, we then trained a large number of participants as well as pioneering Team Leads and System Analysts and toward the end of this phase, a full scale Concurrent Design Facility was implemented as well as a first hosting of CDP4-COMET, the software used as Concurrent Design Platform to create an integrated design model. The pilot was evaluated thoroughly and successfully, and prolonged with what we call a scale-up phase to reach ESA performance levels. While originally, the plan was that the organization would be trained to have their own Team Leads, and transferring skills to the support team was the key priority, this plan was altered. The time investment for Team Leads and System Analysts is too high to justify it as a 'side job', and the benefits of an external Team Lead were well recognized. This shifted the focus from training the support team to another key area of improvement; model based and data driven design and decision making.

While over 150 people were trained to familiarize themselves with the modelling platform for Concurrent Design CDP4-COMET, only few studies used it. Instead, most studies were supported primarily with process guidance. Some also were supported with a modeler who worked in excel or access to create overviews of system data and to calculate effects of design choices. However, few studies used the full capability of Model based Concurrent Design, and if some modelling was performed, it was mostly done by a designated modeller for the support team, not by the domain experts in the Concurrent Design Team. Given the clear need and Dutch MOD's ambition to support their teams in making more data driven decisions during the process, a new strategy to transfer MBSE practices was identified.

CONCURRENT DESIGN AND MBSE

Concurrent Design has had an integrated design model at the 'roots' of its approach for over 25 years. At that time the engineering model was focused on SWP budgets and key design drivers, but already the key premiss of MBSE, having one single point of truth that is interconnected to avoid mistakes in 'copying' information from one document to another has always been a starting point and baseline in the approach. While focussing on early phase design, CD also prescribed a lifecycle perspective involving not only engineers and end-users but also experts on compliance, costs, risk and planning.

MBSE was first coined a few years later, and developed in the System Engineering communities of Incose and the SysML language played a key role in its development. While System Engineering has brought rigor and relevance to the engineering process by structuring it in phases and ensuring an iterative approach with frequent verification and validation creating a loop between requirements and design, Model Based System Engineering brings that rigor to a next level. In a document based engineering process, requirements are subject to interpretation and complex user requirements are extremely difficult to capture, with lengthy requirements documentation that often includes incomplete, ambiguous and conflicting requirements. Project managers struggle to ensure validation and verification is done correct and precisely, and often fail to identify and analyse alternative solutions to trade-offs identified in the design. A Model Base approach will enable more scrutiny in verification and validation creating direct links between the design and its requirements. However, it poses a new challenge in involving end users in the design, as trade-offs are analysed within the complex modelling environment, making it hard for end-users to understand the complexity of the trade-off and the (im)possibilities of the design challenge.
Therefore, MBSE is strengthened by the combination with Concurrent Design to involve all key stakeholders including the end-user in an early design phase. Today, Starion and ESA are collaborating in merging various Domain Specific

modelling tools in their Concurrent MBSE environment based on CDP4-COMET, enabling experts to not only submit and use data to the integrated design model, but to 'round-trip' data from their domain specific models into the overall system model and back to ensure seamless interoperability. CDP4-COMET is the linking pin hosting the integrated design model that enables overall calculation of SWP budgets as well as full traceability of requirements. Using CDP4-COMET for MBSE ensures that domain experts in the study take ownership of the data and collaboratively create a MBSE model.

TRANSFERRING THE CD & MBSE COMBINATION

While the combination of CD and MBSE seems obvious, the transfer of the more technical model based approach was not straightforward. Several challenges were experienced when implementing such an approach at the Dutch ministry of defence.

1) Not all stakeholders are used to work data driven. Military decision making is operational in nature, and focused on making decisions under high uncertainty. A more rigorous fact based approach requires a mind shift.
2) Data is often not available. In the purchase role, a lot of system information is located at the supplier and not available easily before contract. Collaboration with a supplier is often difficult due to procurement laws.
3) The system design is often considered a task of the supplier. The organisation policy is to buy 'of the shelve' products, although these often come with many customized features, the general perspective is "we don't design, we specify now and modify later."
4) Many stakeholders are not engineers, and system engineering is not adopted in all engineering departments, therefore modelling is often a new skill and practice for participants.
5) Many stakeholders don't know what MBSE is, and it is often mystified as something very complex and difficult.

To accelerate the CD support team came up with a strategy to increase the use of MBSE in the studies, consisting of three pillars: 1) Increasing emphasis on a data driven decision making in the intake, to convince the project manager to adopt a model based approach. 2) Training domain experts in MBSE, offering training courses as well as 'on the job' support in creating models to analyse the system specification and it's feasibility, and 3) Supporting teams to create model based success stories, studies where models brought clear added value.

We will briefly sketch some examples of each of these steps.

THE INTAKE, CONVINCING STAKEHOLDERS TO MODEL

A key step in the Concurrent Design process is the intake process. A series of 2-3 meetings are organized with the CD support team and the core team to understand the scope of the Concurrent Design study, the objectives, intended results and the relevant stakeholders. In this phase, the need for an integrated design model can be discussed. However, often the project responsible is used to work on a text based specification, and they need Concurrent Design to speed up this process. Introducing MBSE at this point will seem like more work and a delaying factor rather than an increase in efficiency.

In one of our studies the project manager understood the value of data driven decisions, and embraced the idea of a model based approach. However, he insisted to not 'bother' the stakeholders with the modelling, and to only present the results of the modelling effort at the final session. This put the CD support team in a difficult position to model the system in one-on-one sessions outside the CD cycle. However, a hybrid solution was found in presenting results as well as missing data to the team in PowerPoint, transferring the data to CDP4-COMET in the background, supported by the system engineering.

In another study, the project manager was very enthusiastic about the model based approach and encouraged the CD support team to engage the CD team in a modelling effort. With a lot of enthusiasm we presented the model and its objectives, the data that was required and the process we envisioned. This time the challenge was found in filling the model, and reaching a sufficient level of completeness. Some stakeholders didn't have the required information and others did not have time to provide the required information. After several iterations the model was still not sufficiently complete to do the system level analysis that was intended.

A final case was one where a model was re-used. In an efficient session with only key stakeholders that had access to the required data we filled the model and ran the analysis. The result was not very positive and would press heavily on the budget. Instead of dealing with this inconvenient result, the project manager dismissed the model and relied on conventional heuristics instead.

From these experiences we learned that a very broad commitment to a modelling approach is critical. It takes time to convince stakeholders, and they may not all contribute to the model directly. Offering simple ways to contribute to the

MBSE models will enable those without a modelling background to contribute to the model, but also, the results of the model should be clear and well presented to ensure participants understand the value.

TRAINING, TEACHING MODELLING SKILLS

A second approach to transfer MBSE is to use training. As described in [1] we have successfully trained many stakeholders in the practice of Concurrent Design. Part of those training sessions is an introduction to model based design. We build several modelling challenges that we describe below.

The first introduction to a model based approach is part of our introduction game for Concurrent Design. In this 1 hour game [2, 3] we let people experience concurrent design in a role-play fashion. At the end of the game, we show how a model could support the team in comparing options and making some of the design decisions. The model is pre-designed and only demonstrated. The participants don't actually have to do any modelling, however, they see how the model supports the decision making process, and can assess applicability on a very concrete case.

The second, advanced training program originally involved participants to actually model a small system. The training was designed in a way that some of the model was already pre-structured, and participants had to specify things like mass and costs for a sub-system by searching for available components on the internet. One of our trainees even called a supplier abroad and was stalked by the sales department for another 2 weeks! While this exercise was fun for some, others found it really difficult. It was time consuming and before we had a complete model, sufficient to run a mass budget, some participants lost interest. To resolve this, we resorted to a setting where participants received a list of pre-modelled equipment. Instead of modelling it themselves, they choose an equipment out of two options and add this to the product tree. The resulting model can be created in a shorter time, and it requires very little effort in the CDP4-COMET tool. In this way, the trainees see the effect of a model based iteration, and can even optimize their design by changing their choices, without the need to operate the tool.

The second approach was much more comprehensible for most of the trainees. In this approach the difficulty of a new tool did not distract the trainees from learning how the tool can support them in their effort. Some participants actively asked for a more in-depth training to learn to use the tool.

With respect to the tool training, learning how to use CDP4-COMET software, as well as the modelling principles, we learned that this should be taught shortly before using it for a real scenario. In this way the training will better 'stick' and is more effective. Furthermore, it makes sense to train only the parts of the tool that a participant will use. MBSE software has many functions and features, but if they are not used, they easily create an overload. Focussing the training on what the trainees need to use is most effective. Finally we created 'homework' exercises to re-practice the model operations manipulations taught in the training. Adding short video's with instructions on how to perform the modelling step will help trainees to refresh their knowledge.

EXAMPLES AND SUCCESS STORIES

A final and important way to convince stakeholders to adopt a more model based and data driven approach to design and system engineering is through success stories. While the training models give a good illustration of the capabilities and advantages of a model based approach, they do not show 'how hard it is' and neither do they give insight in the iterative process of modelling. Having sufficient first hand success stories and demonstrating the actual models created for real life cases remains our best tool in convincing stakeholders. This snowball effect is slow, as a model based project takes time, and some of the models cannot immediately be shared or demonstrated due to confidentiality. However, the credo 'learning by doing' does apply, having real examples is important.

CONCLUSIONS

Our approaches show a rocky road, implementing MBSE even in combination with Concurrent Design is not easy. A large variety of domains and stakeholders involved does not help; reuse opportunities are sparse and difficult to identify. However, having the Concurrent Design approach as a basis for projects makes it easier to introduce a model based approach, even when a modeler rather than the entire team creates the model. Our MBSE effort stays focused on the most complex engineering projects, where a model based approach will have most effect. The Dutch MOD is persistent in its effort, providing the long term transition focus required to create such profound changes, which enables Starion group to innovate, adapt and enhance our approach to training and transfer of this critical skill.

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