Development of a Microsatellite mission using MBSE approach

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Introduction and Overview

Creotech Instruments S.A. is a leading Polish provider of advanced space technologies, specialized electronics, and hardware with global applications in such areas as quantum computers, quantum cryptography, quantum physics and high energy physics laboratories.

The Company's short-term goal is to finalize HyperSat, a program seeking to deliver a satellite platform for microsatellite space missions and microsatellite constellations. HyperSat will be competitively priced and offer superior component quality and reliability. A key point of the program will be the launch of EagleEye, a proprietary observation microsatellite, slated for the middle of 2024. For the Eagle Eye mission, Creotech decided to leverage MBSE for three main purposes:

1. System design in context
2. Continuous engineering process from requirements to detailed engineering
3. Leverage model data as a basis for stakeholder communications

Experience gained in this process is now being used in subsequent projects such as PIAST and Seagull.

EagleEye microsatellite overview

The EagleEye, an Earth Observation microsatellite, is part of the HyperSat satellite platform, an initiative to create a product platform that achieves competitive commercial and reliability ratings through maximizing re-use of design concepts and technology.

The EagleEye microsatellite platform has a mass up to 100kg, an orbital life span of up to five years in LEO and is primarily used for earth observation [1].

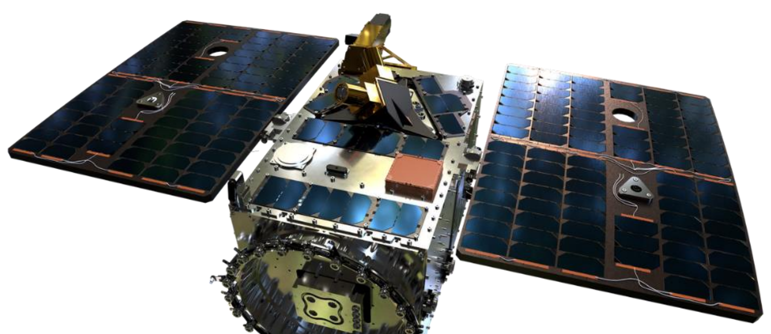

Fig. 1. EagleEye Earth Observation microsatellite.

MBSE and Creotech's Design Environment

Creotech develops space technology from the perspective of three involved constituencies:

1. The Creotech Design Environment (also referred to as the Designing System)
2. The System under Design itself (the EagleEye satellite)
3. The System Context, representing all the interactions the System under Design must be aware of.

The perspective of developing satellites both in the context of the HyperSat product platform and in the EagleEye system context lead to employ MBSE as the system development framework to be used.

Challenges and Goals of the MBSE Initiative

However, the development context in which Creotech products are being developed, posed three main organizational challenges to a MBSE implementation:

1. **Risk**: The Creotech design team was new to MBSE, and the lack of experienced systems engineers posed a certain risk due to the unfamiliarity with MBSE and possible - yet not clearly known - additional efforts, such as overhead work or MBSE training efforts
2. **Awareness**: Both Creotech's engineering and management were initially not aware about the value a systems engineering approach based on MBSE would bring. In addition, Creotech's commercial partners were also early in the adoption of MBSE.
3. **Communication with external stakeholders**: Most of the communication with external stakeholders today is still document-based. This holds the risk of inconsistent information between model data and information provided in documents.

Despite these concerns, the EagleEye project presented a unique opportunity to "do it right" from the start. Creotech decided to take the opportunity for a systematic and methodically comprehensive implementation of MBSE. At the same time, a stepwise approach, and a conscious effort to bring all stakeholders on board were taken.

Solution Approach

The development context also incorporates development software tools and the IT environment. In the case of Creotech, established solutions and processes had been in place for requirements engineering and detailed design, especially electrical, harness and communication.

One of the key benefits expected from an MBSE approach was a continuous and bi-directionally associative flow of information between requirements management and detailed engineering.

This meant that the integration of existing software applications into a to-be-decided MBSE environment would be of high importance. At the same time, external stakeholders would still be requiring written documentation, which would need to be at least generated from within, if not directly integrated into the modelling environment.

Technology and Vendor Selection Criteria

It became clear early in the process that the selection of the MBSE software platform to be used would play a key role. This became even more apparent as MBSE tools do impose - at least partially - a certain modelling approach that must be compatible with the development processes used or desired.

1. Consistency of model data: The tool should ensure that all data within the model is always consistent without requiring any manual consistency checks.
2. The MBSE tool to be selected would have to integrate bi-directionally into the harness design tool, so that model product structures could be used to feed the ECAD software.
3. The MBSE tools would need to integrate with the existing requirements management tool.
4. Collaboration (both within the design team and with external stakeholders) should be enabled with collaboration, tracking and versioning functionality.

Key vendor selection criteria were:

- **Eye-level and agile**: There was awareness about the fact that the integration especially into downstream design tools, while not out of the ordinary, might require functional changes and alterations not only on model - but also on software level. Creotech, being a mid-sized corporation, would hence look for a technology partner on eye-level with a direct rapport into the software vendor's engineering organization
- **Space industry and detailed design experience**: The MBSE software provider was expected not only to provide technology. Given that Creotech was about to take their initial steps towards MBSE, it was deemed critical to collaborate with the vendor on several levels, including the creation of a suitable reference model that would include a product structure for downstream harness design integration.

Implementation Approach

Creotech opted for a five-stage implementation process:

1. MBSE software tool selection: This included the above criteria with a critical examination of the underlying development method of the tool. It was decided that Zuken Genesys as a tool together with its underlying STRATA method would fit the selection criteria.
2. Using the existing requirements management software ReqView, basic Systems Engineering concepts such as requirements capture, and requirements verification were introduced into the development process.
3. On top of the existing software environment and the now established basic SE processes, Genesys was introduced as the modelling tool.
4. Building out the product architecture for the Eagle Eye satellite in Genesys, the integration between the model and the harness design was initiated.
5. As a last step, an internally developed bridge tool was introduced to integrate the requirements management tool with Genesys. This was done with the goal of moving certain SE functions currently mapped in the requirements tool to the MBSE tool and establishing a bi-directional connection between the tools.

As the knowledge on the MBSE and its use has been growing in Creotech team, the following two steps are envisioned as area of further advancement towards digital engineering:

1. Introduction of Genesys as a go-to tool for mission modelling. This is currently ongoing as part of one of the early phases of ESA planetary mission which Creotech is leading.
2. Using MBSE for product line engineering.

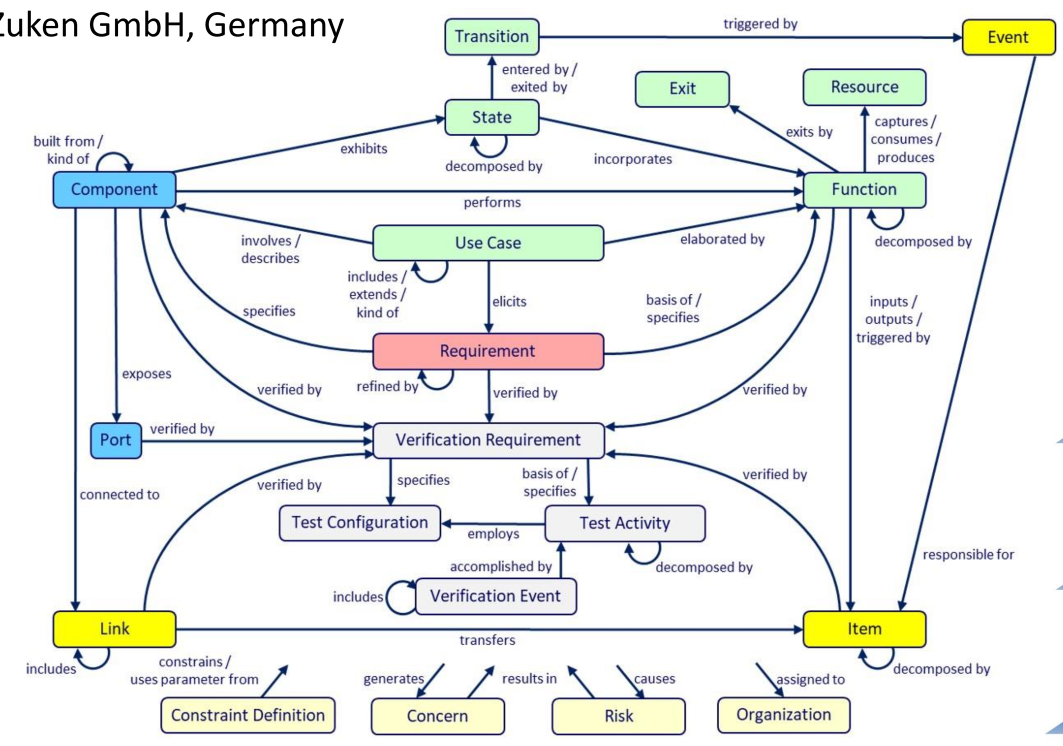

Fig. 2. Comprehensive Systems Design Language: Driving MBSE adoption using natural language modelling. [2]

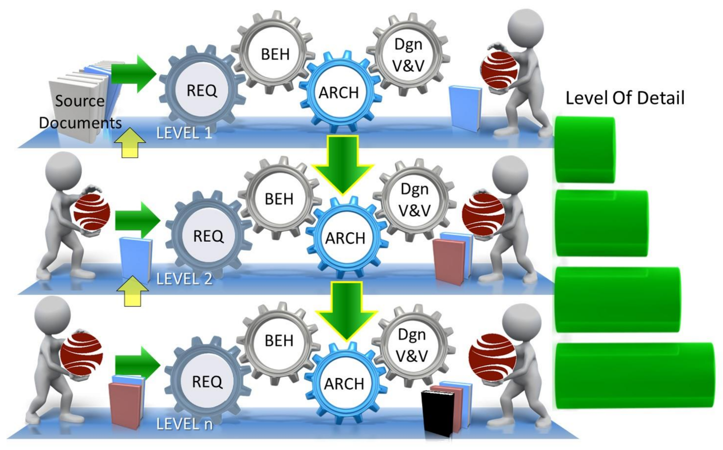

Fig. 3. STRATA layered methodology [2]

MBSE in use for the Design of the EagleEye Satellite

Method implementation – a layered perspective

The STRATA method implementation, native to Genesys, was found to represent a development approach in line with the design principles employed by Creotech: It is a layered, top-down approach that starts with the definition of system context, then details into system and subsystem level. At each level, requirements, behavior, architecture, verification, and validation are defined respectively to the level of detail [3].

Based on the STRATA concept, the EagleEye MBSE model consists of three main levels:

1. On the System Context Level, high level requirements, behavioral and architectural structures are created in conjunction with the corresponding level of validation and verification elements. Mission requirements are synchronized between the requirements tool and the MBSE tool. These requirements are the basis for the design of the highest behavioral structure and the system architecture level in the model.
2. The satellite level represents the next level of detail with the core functional structure and the main physical subsystems, such as electrical power, on-board computer, attitude management, payload, and communication. V&V on this level are created as part of the model and then fed back into the requirements management system.
3. The subsystem level represents the full electrical and communication architecture of the satellite, including all electrical and electronic components and their respective pinouts. This level of product structure detail in the model allows for a direct integration into the electronics and harness design tools.

Connecting Systems and mapping functionality: integration with external software

One of the fundamental engineering concepts employed was treating the model as the "authoritative source of truth": The model serves as the source for upstream (requirements) and downstream (design) systems.

1. Downstream:
Data from the model feed electronic design (Altium Designer) via a manual data import and harness design (Zuken E3.series) via a Genesys to E.3 connector. Additional automation is still in progress.

2. Upstream:
Upstream integration into requirements management software (ReqView) occurs on three levels of data: Requirements, Validation and Verification and FMEA and FDIR. The model held in Genesys holds the requirements structure, validation and verification and provides connections between them. Requirements and V&V are synchronized between Genesys and ReqView, using an in-house bridging tool. FMEA and FDIR are implemented in the ReqView, but are based on the FMEA schema in Genesys.

Model as a source of true – real life example

At the current stage of MBSE implementation, the model is a sufficient source of true for everyday engineering work and as a way of communication between system engineers and engineers of specific branches. As an example, a designer of a specific subsystem has an easy access to one place, where it can find all required information:

- requirements, with provided traceability, which is a driver for e.g. electronic engineer for the PCB design.
- interfaces, with interconnections on the subsystem level and traceability to unit/system level (model is the ICD):
  - Each electrical interface is described with at least: type, data, pinout, part number. Color-coding of connection type (board-to-board, harness, etc.) on a diagram is introduced to increase readability.
  - Views are customized, depending on the engineer needs (logical ICD for the software engineer vs. electrical ICD for the electronic engineer)
  - Integration with ECAD software and harness tool reduces amount of work and mitigates risk of non-integrity.
- functional description (including function allocation and activity diagrams) with traceability to other levels. This also incorporates FDIR activities.

All this required content can be easily exported in a form of interactive HTML document (hosted on a company server), so there is no need to directly use the software by the domain engineer. Moreover, minor updates of the model can be also done via plugin to MS Excel.

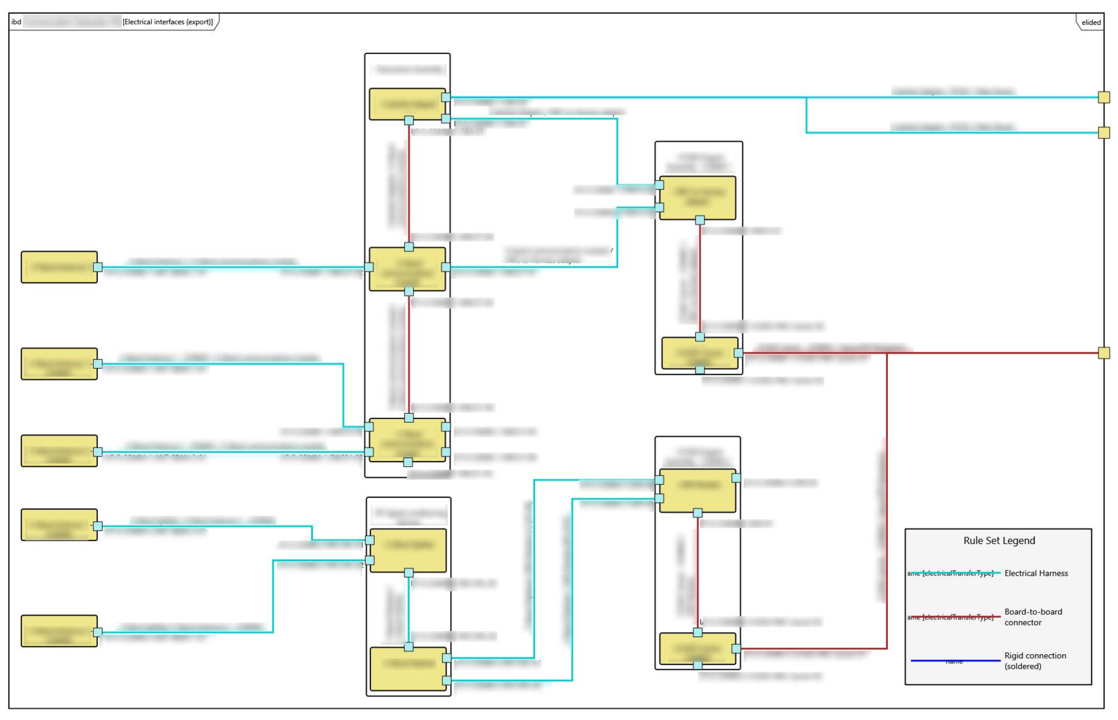

Fig. 4. Block diagram of the electrical connections for one of EagleEye's subsystems. Names are blurred so as not to divulge detailed design information. Units are presented as blocks, grouped into assemblies (by black frames). Ports are exposed for upper and lower level connections.

Results today

The MBSE team at Creotech was convinced that the benefit of embracing MBSE would only fully unfold if:

- The model would represent the "authoritative source of truth" for all development information,
- Internal and external stakeholders and their systems and information types (i.e., written documents) could be integrated into the modelling environment,
- The model itself would go beyond the usual descriptive nature of MBSE and describe the full electrical and communication architecture of the satellite.

Two of these goals have been accomplished: the first and the third. The second has been partially accomplished, as involvement of external stakeholders to the modelling environment is still to be figured out.

At the same time the following has been observed:

- MBSE has proven to be a valid approach and is being adopted by the organization.
- The models created in the MBSE environment serve as the sole source of truth for engineering.
- Models are being re-used and are the basis for an internal product "library."

Finally, the structured and methodical MBSE approach Creotech has adopted is an increasingly important competitive differentiator.

References

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[3] Long D., Scott Z., *A Primer For Model-Based Systems Engineering, 2nd Edition*, 2011.