Applications of Model-Based Systems Engineering for JAXA's Engineering Test Satellite-9 Project

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1. Introduction

JAXA's Engineering Test Satellite-9(ETS-9) project team is applying Model-Based Systems Engineering approach to the interface management of flight system development. Launching in the early 2020s, ETS-9 demonstrates the all-electric spacecraft technologies for the next generation communication satellite including the newly developed Hall Effect Thruster System as shown in Figure 1. The Hall Effect Thruster System consists of the three main components: the thruster, the power processing unit (PPU), and the propellant flow control module. The power processing unit controls and monitors thruster system performance. The comprehensive understanding of a complex Hall Effect Thruster system is a challenging issue for project systems engineers due to the complex interaction between components developed by different providers.

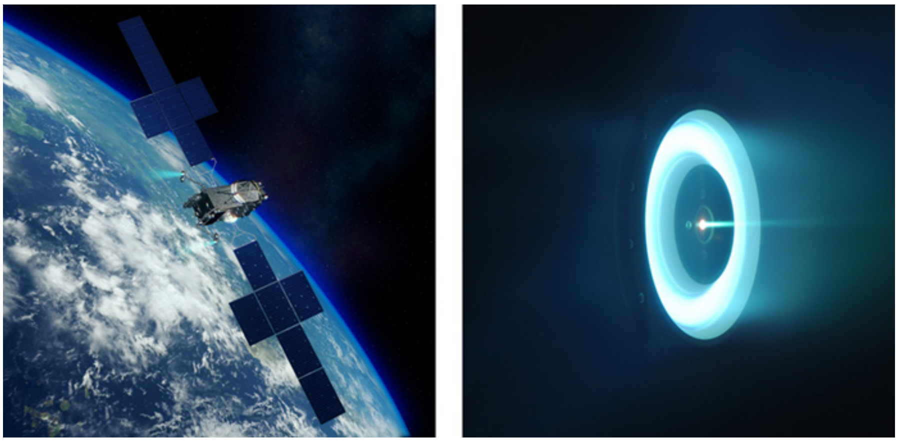

Figure 1: Artist concept for ETS-9 Mission (Left) and performance test of Hall Effect Thruster (Right)

2. How do we manage the complexity?

The main idea of our approach is a comprehensive system analysis supported by a system model and interactive digital artifacts that visualize system analysis results extracted from a SysML system model. We manage the system complexity by using the formalized descriptions of system requirements, behaviors and behavior allocations to system elements with SysML. We describe the system behaviors as sets of interactions between components by using the object flow of activity models. The object flow includes the electric energy, the xenon gas, information and the force generated by the thruster. This behavior model is expanded to the failure mode analysis by customised descriptions of the failure modes. We extract systems engineering products as html based interactive digital artifacts from the SysML model by using Python graph theory packages and data visualization packages. These digitalized systems engineering products support systems engineers to understand and analyse the complex system. The flow of extracting systems engineering products as an interactive digital artifact is shown in Figure 2. The prototype of interactive digital artifacts that support the system analysis and the failure mode analysis are shown in Figure 3 and Figure 4.

3. Conclusion

We present the practice of Model-Based Systems Engineering approach to the actual flight project focusing on the interface management of the Hall Effect Thruster system. The proposed system model and the interactive digital artifacts guide the system level analysis of the Hall Effect Thruster System supported by model queries and visualization of the hierarchical structure of system architecture. We find the effective use of MBSE application to the failure mode analysis in the implementation phase of the ETS-9 flight project.

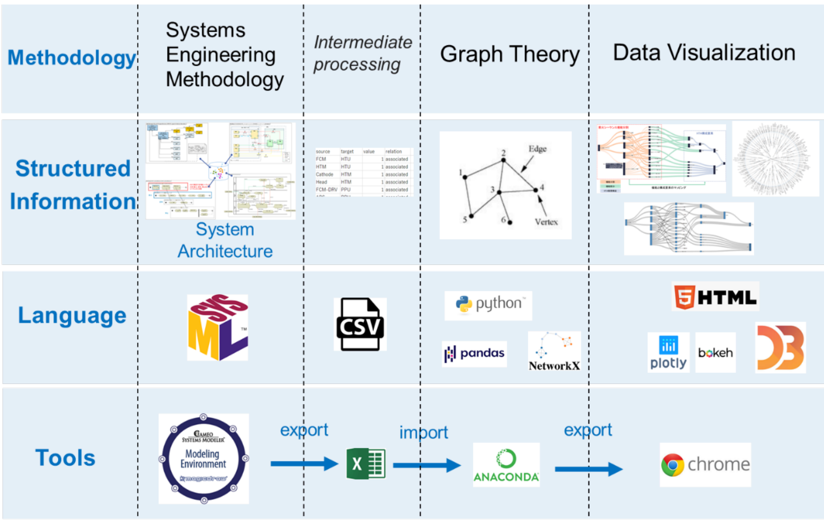

Figure 2: Flow of extracting interactive digital artifacts from a SysML model

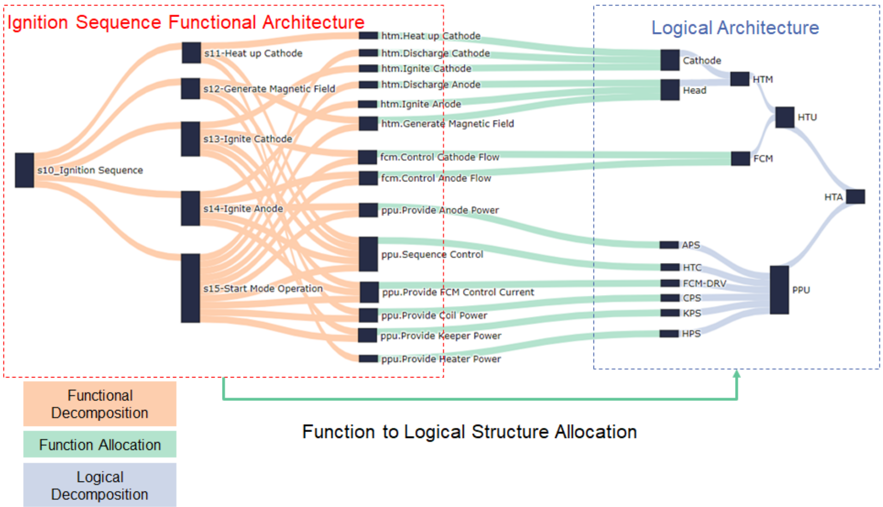

Figure 3: Interactive Sankey Diagram supports understanding a system of interest

Figure 4: Interactive radial failure mode hierarchy maps created by Python and D3.js