Application of the ‘Federated and Executable Models’ MBSE Process to Airbus Orbital Servicing Missions

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DEFENCE AND SPACE

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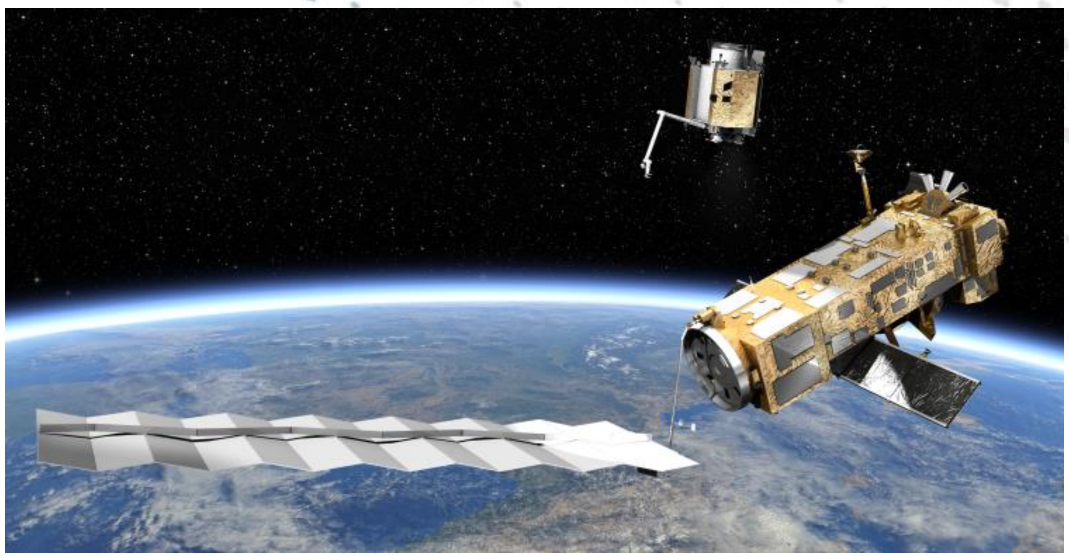
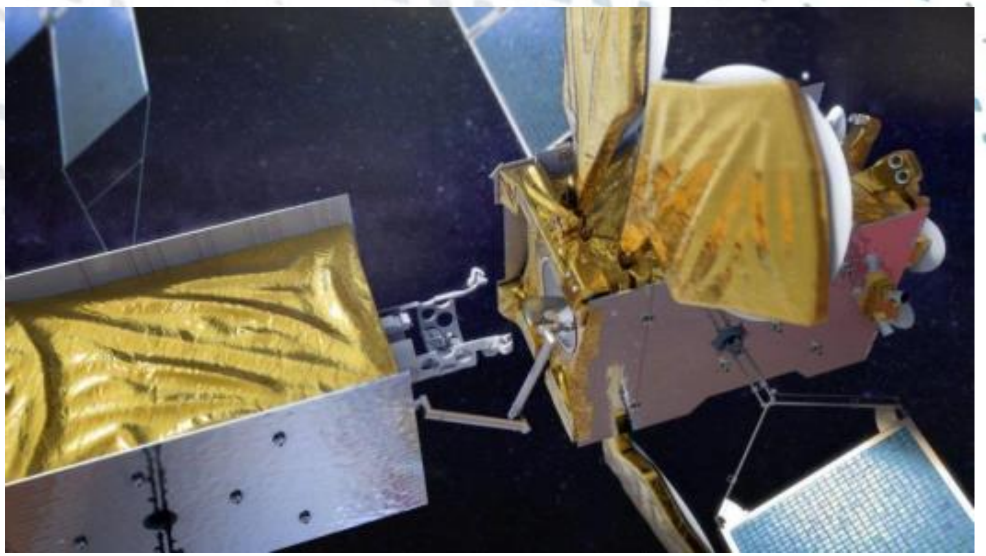
Airbus Orbital Servicing Missions



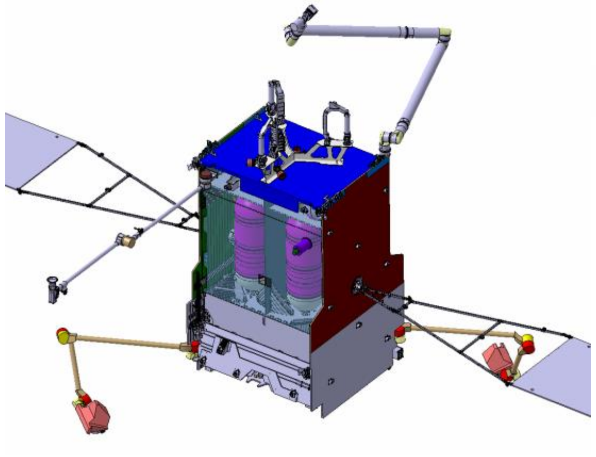
Active Debris Removal

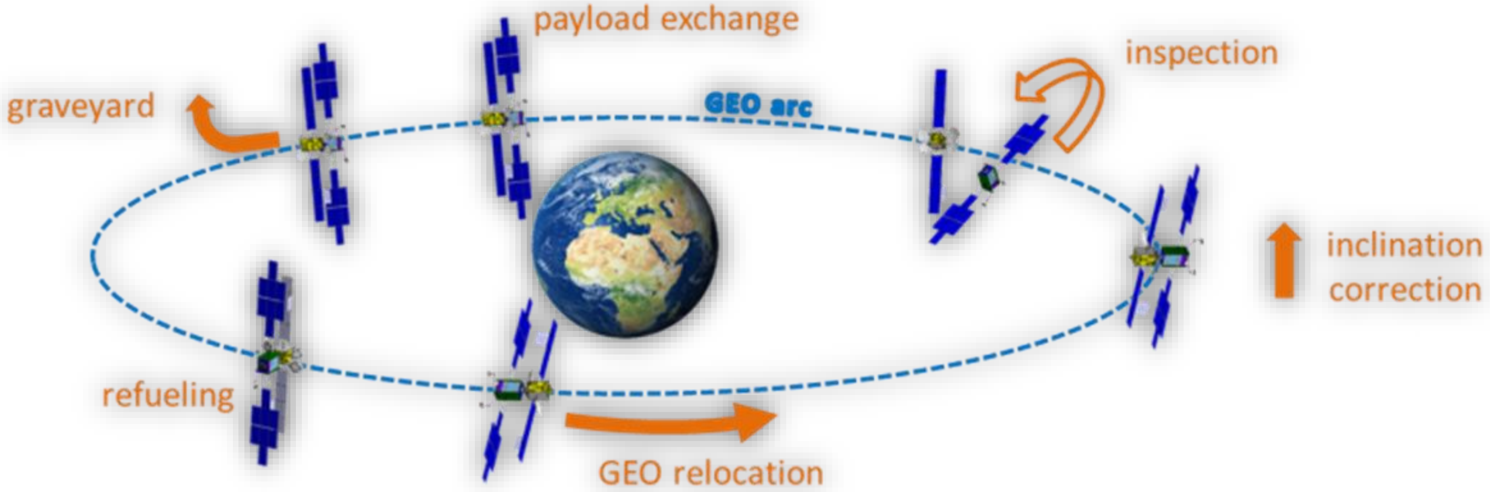


Space Tug Geo-Servicing

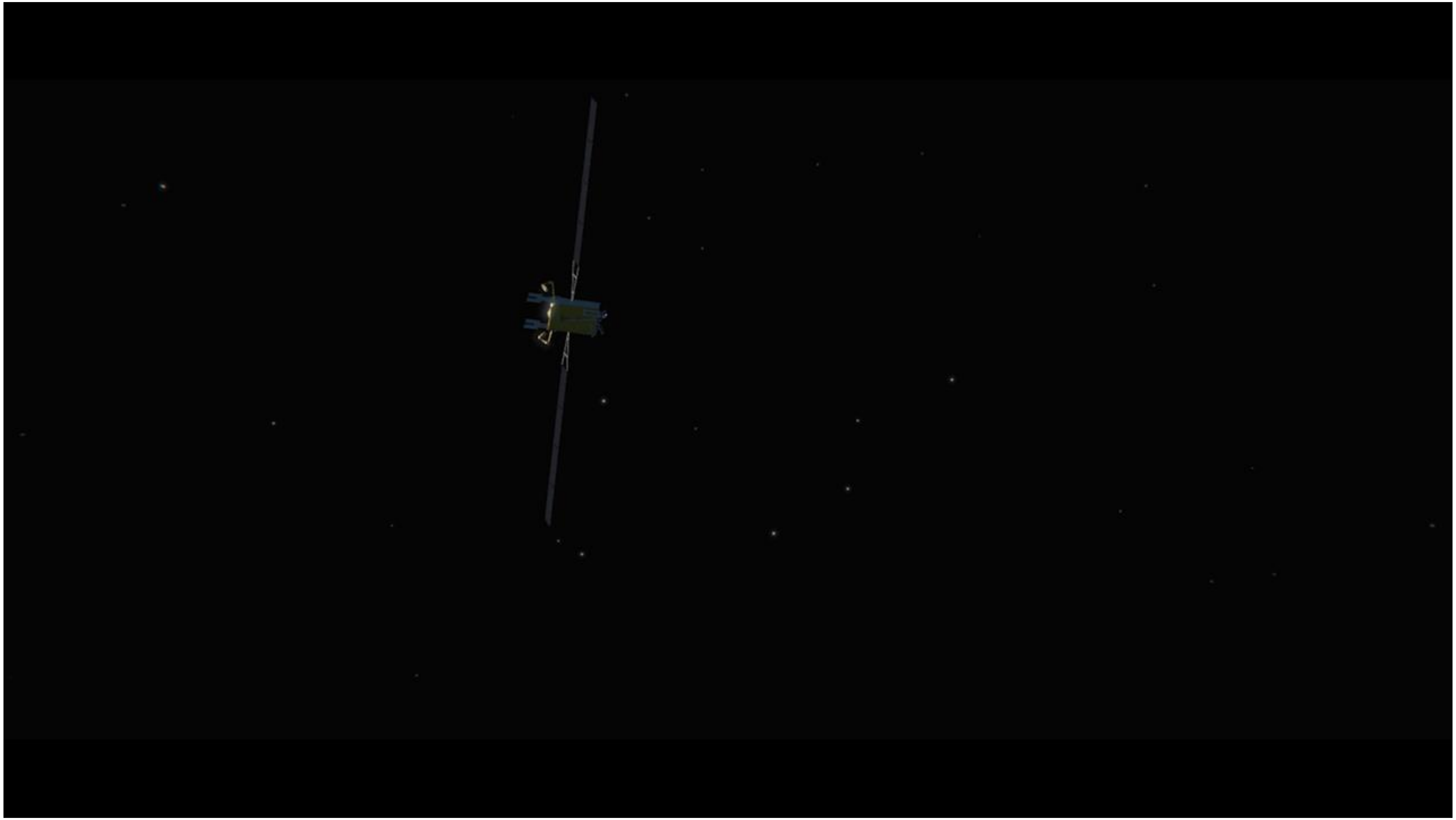
Airbus Space Tug vehicle for new services in Geostationary orbit

- **Inspection:** external monitoring of the Satellite (e.g. camera) to check its status or its environment
- **Relocation:** tugging the Satellite to a different GEO orbital slot
- **Graveyarding:** tugging the Satellite to a graveyard orbit at the end of its lifetime
- **Inclination removal:** tugging the Satellite from an inclined orbit to a new requested inclination (e.g. 0°)
- **Refueling:** in-orbit refuel/refill Satellite's tanks
- **Continuous SK:** ensuring full AOCS of composite <Satellite+Tug>, during n months





Airbus Space Tug vehicle for new services in Geostationary orbit



Objectives and definition of the MBSE process ‘Federated and Executable Models’

The overall ‘Federated and Executable Models’ MBSE process allows defining and validating system properties and architectures, and leads to consolidated system and architecture requirements.

Questions to be addressed by Systems Engineering to ensure consistent design

The system data are processed from mission requirements to system properties to system architectures to design

Mission and user requirements

System properties. Solution free.

What is the system boundary?	What are the main system capabilities?	What is the system mass? Dry mass, propellant mass?	What are the trajectories, accelerations?	What are the lighting conditions?	What are the product geometries?
What is the CONOPS?	What are the system states and modes?	What are the main mission activities?	What is the thrust?	What are the contact times to ground?	What is the control structure?

System technical requirements

System architectures. Development of solutions.

What is the operational concept?	What are the hazards and failure modes?	What is the product tree?	What are the system parameters?	What is the system sizing?	What are the system responses in scenarios?
What are the functions?	What are the safety constraints?	What are the functional allocations?	What are the system budgets?	What is the data model?	What are the costs?

Architecture technical requirements

Selection of technologies.

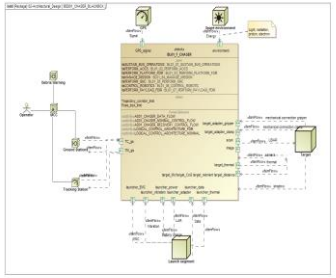
System design

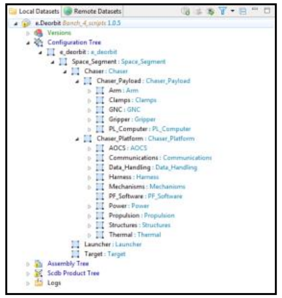
Main data models of the process and data flow

Logical Model
Cameo SysML

Describe logical prop. & architectures

- System capabilities def.
- Mission scenario analysis
- System states and modes
- Functions and Safety
- Architectures



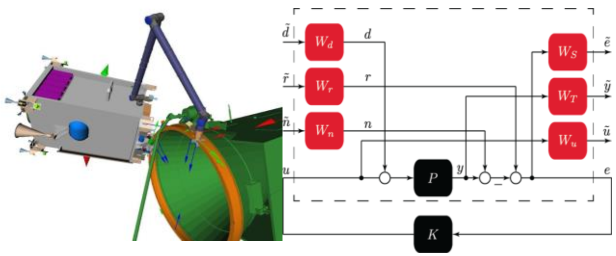


Physical Model
RangeDB

Describe physical prop. & architectures

- Product Tree
- System Budgets
- System sizing
- Physical architecture iterations

Geometrical / Dynamic Model

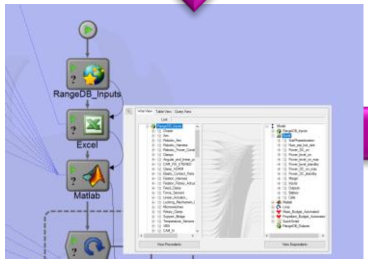


Exchange of model data in standardized data flows

ModelCenter

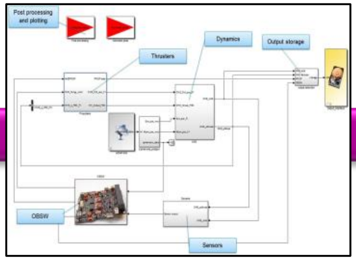
Analyse & Validate System

- Parameter trends
- Parameter coupling
- Optimisation
- Requirements verification



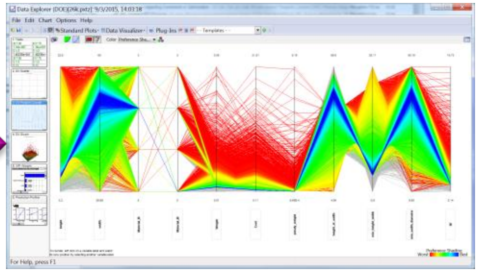
Analysis Flows

Domain Models



Generate physical data

Data analysis



Sensitivity, Optimization

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System Definition

The proposed modelling process addresses each aspect of the system definition.

"A system is an open set of complementary, interacting parts, with properties, capabilities and behaviours emerging, both from the parts and from their interactions, to synthesize a unified whole."

Derek Hitchins (2007)

Systems Engineering, A 21st century systems methodology

Main objectives of the modelling process

- System boundary and context representation
- Mission representation with states and mission activities
- System representation with capabilities, modes and system activities
- System architectures: functional and physical
- System budgets (mass, propellant, power, energy, data link, data rate, …)
- System sizing (structure strength, solar array size, radiator size, …)
- System simulation in scenarios and sensitivity analysis
- System synthesis from the different descriptive models

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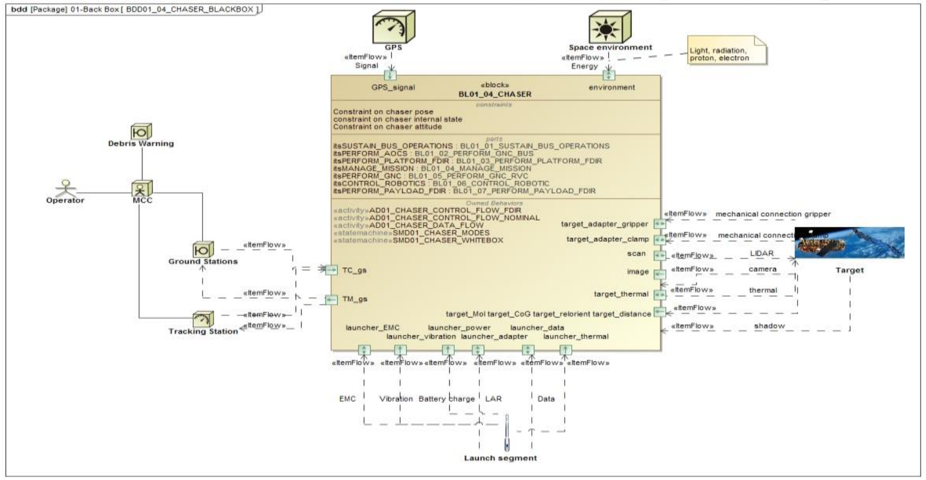
Selected tooling environment for the process implementation

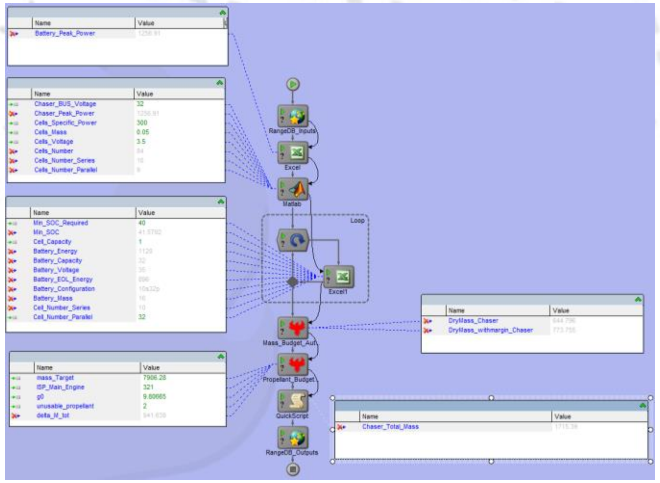
Rely on commercial tools except Airbus DS System Database RangeDB

Data Models	Tools
Physical Model	**RangeDB (Airbus)**
Logical Model – SysML	Cameo Systems Modeler 18.5 (No Magic)
Analysis Flow for • system response, • ‘What if’ analyses and • requirements checks	ModelCenter 12.0 (Phoenix Integration) MBSEPack (Phoenix Integration)
Dynamic model	Matlab R2015a (MathWorks)
Geometry model	CATIA v5 (Dassault Systèmes)
Mission model	STK 11 (AGI)
Sensitivity analysis	ModelCenter 12.0 (Phoenix Integration)
Virtual Reality model	HTC Vive / Unity Version 5.4.2 Cameo Collaborator (Phoenix Integration)

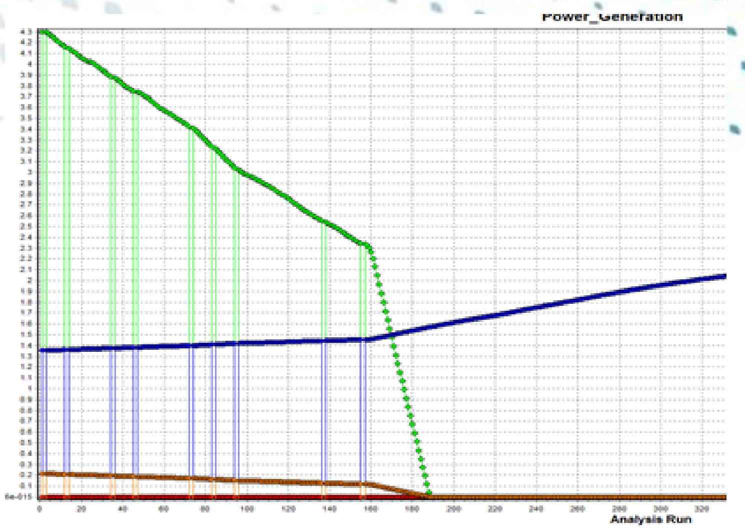
Application of the MBSE process
‘Federated and Executable Models’



Descriptive models



Inter-operability of model federation



Model execution

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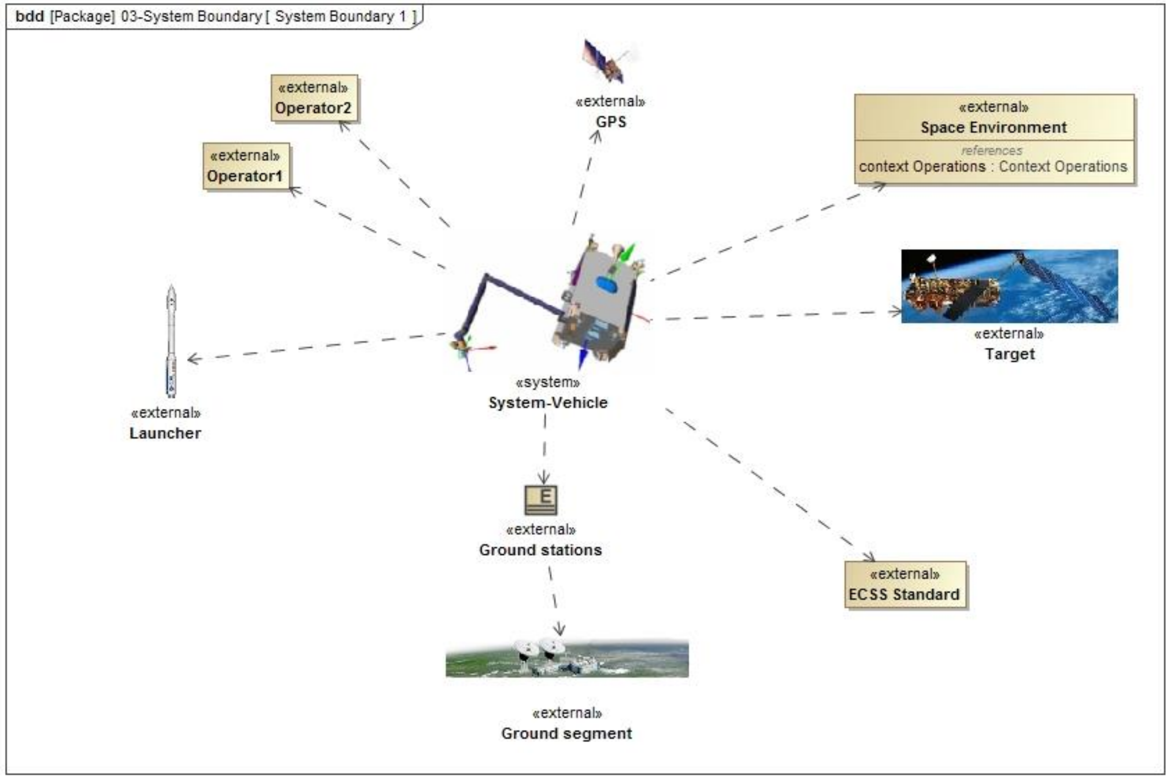
What is the system of interest? What is the system context?

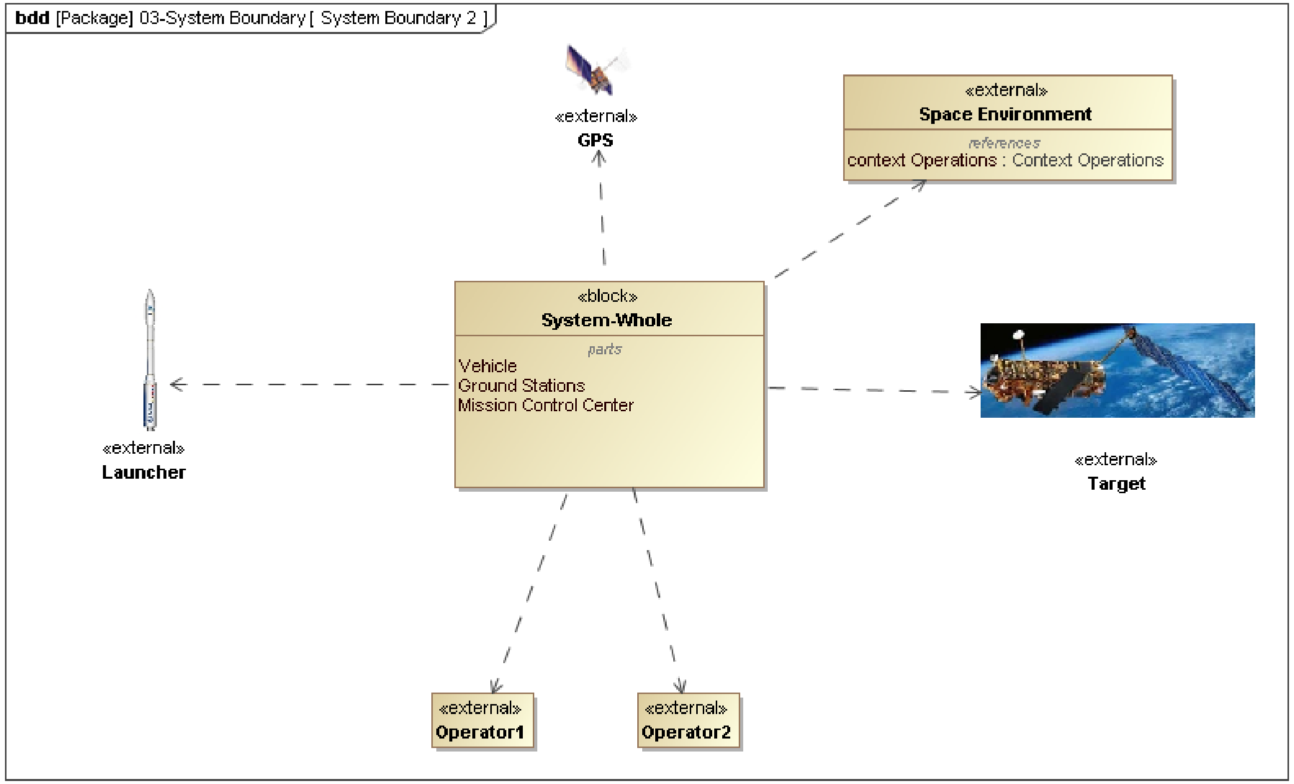
System boundary and stakeholders

Definition of the system of interest and its context

Boundary Solution 1



Boundary Solution 2



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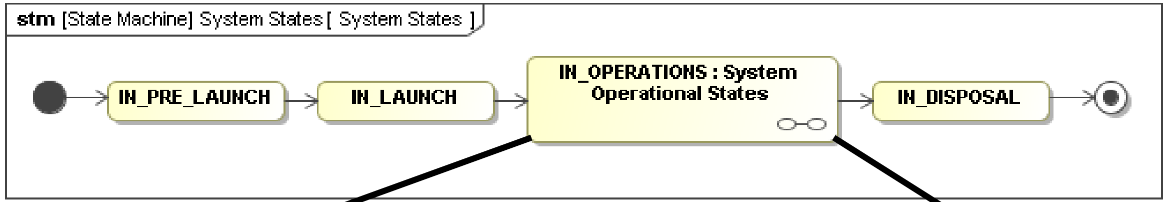
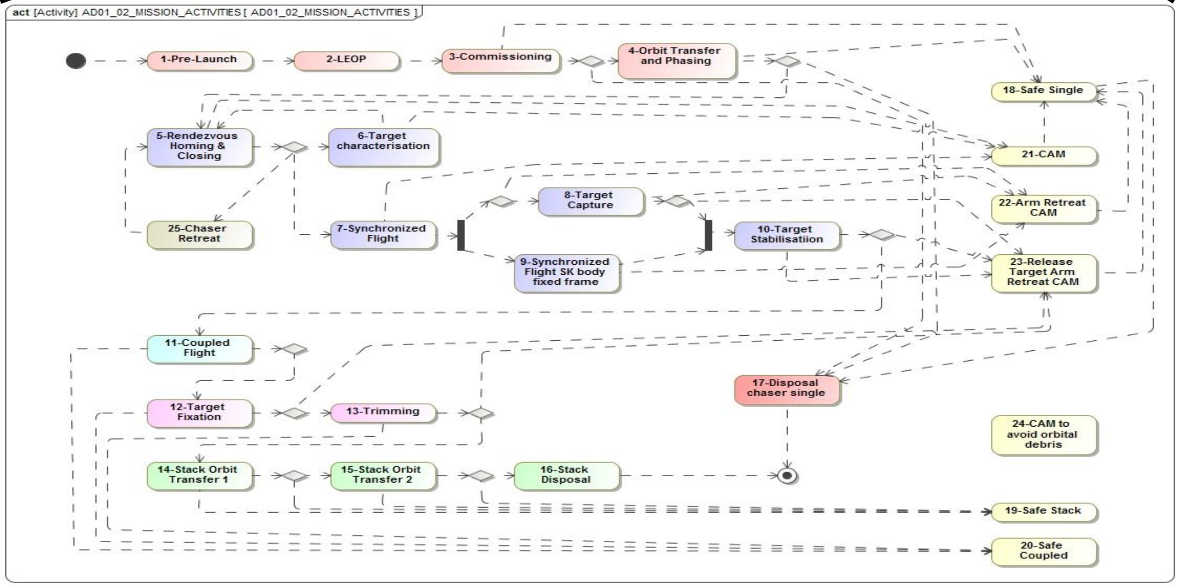
What are the mission scenarios? Which system capabilities and modes are requested to implement the mission?

Mission activities and System capabilities

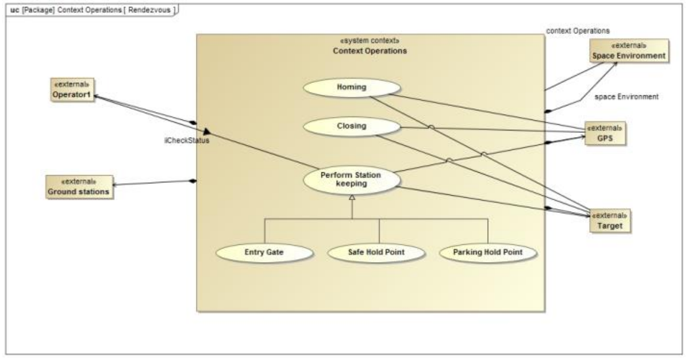
System states

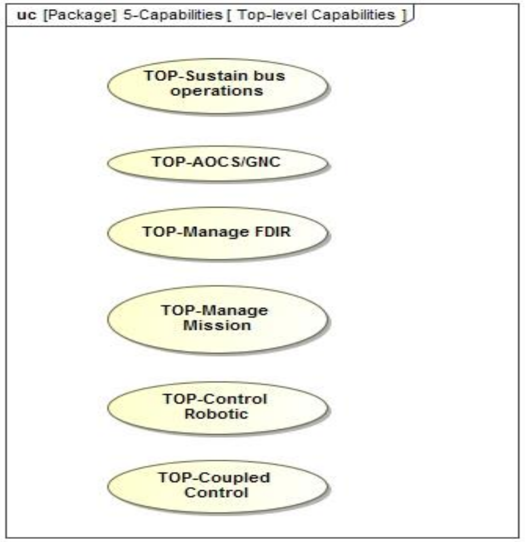


Mission phases and activities

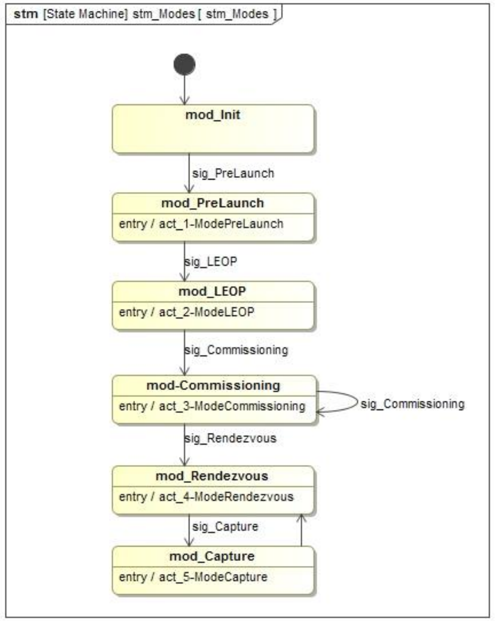


System capabilities (no functions at this stage)





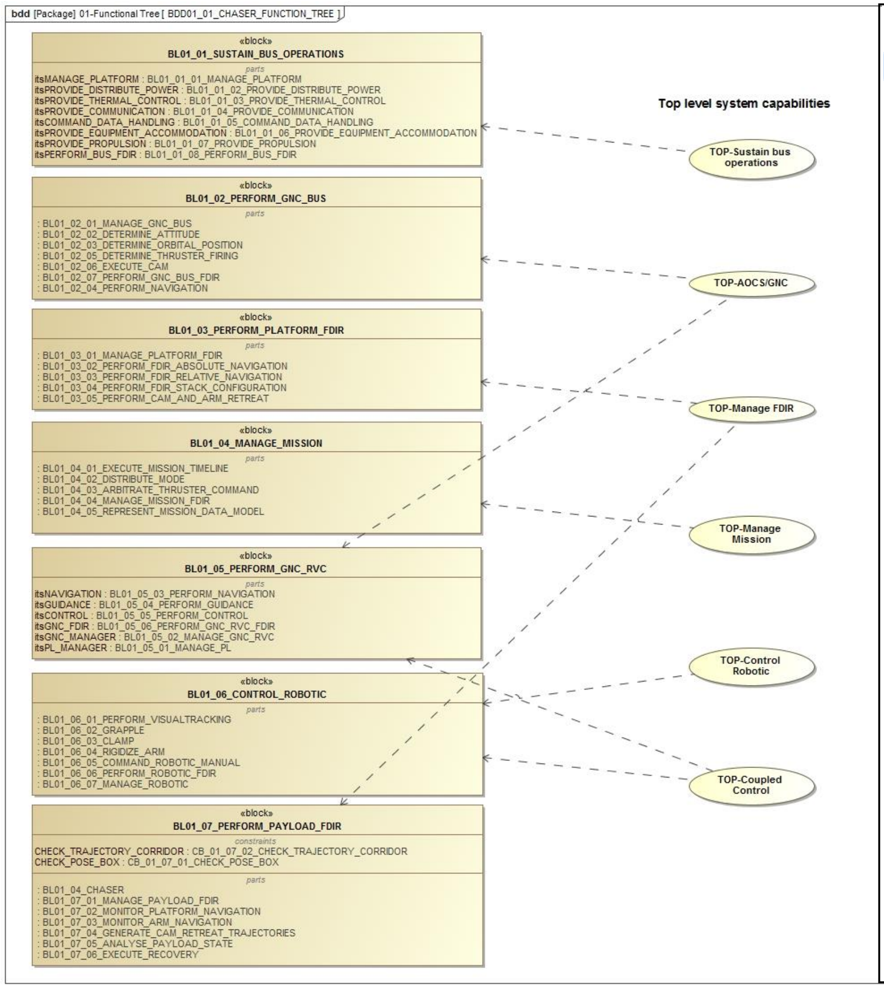
System modes



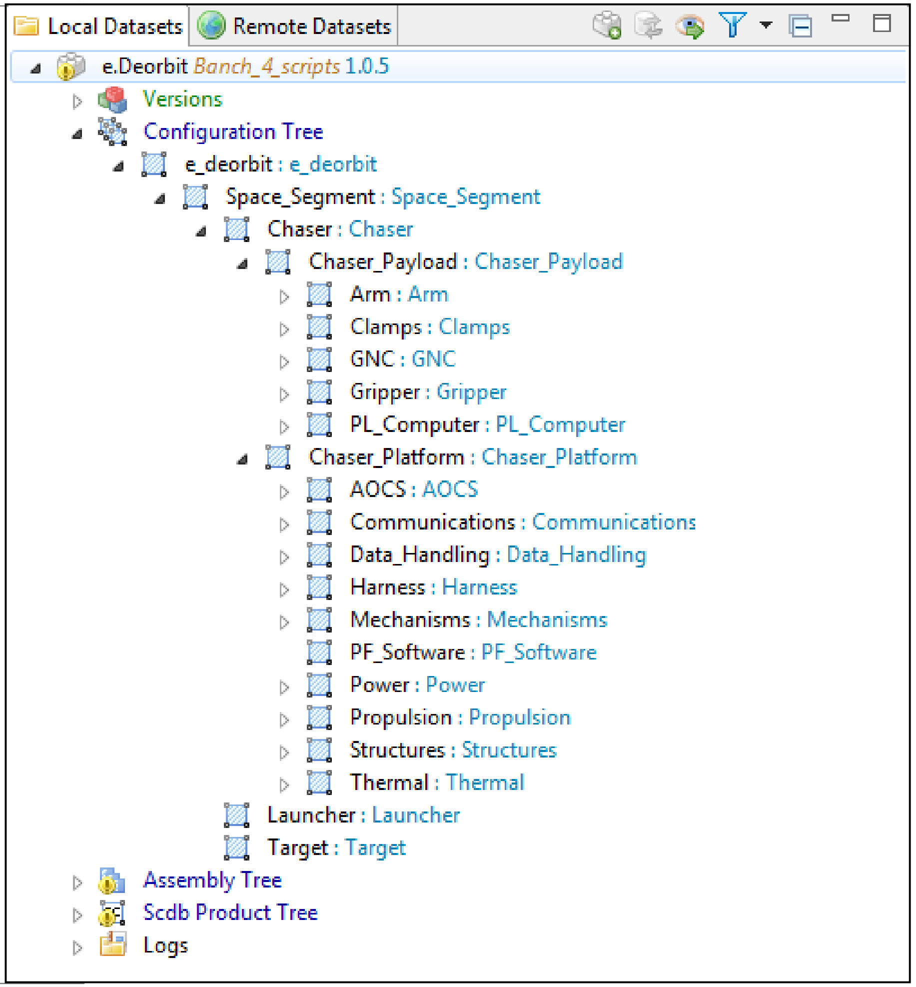
What are the system architectures and budgets needed to run the mission scenarios?

System architectures and budgets

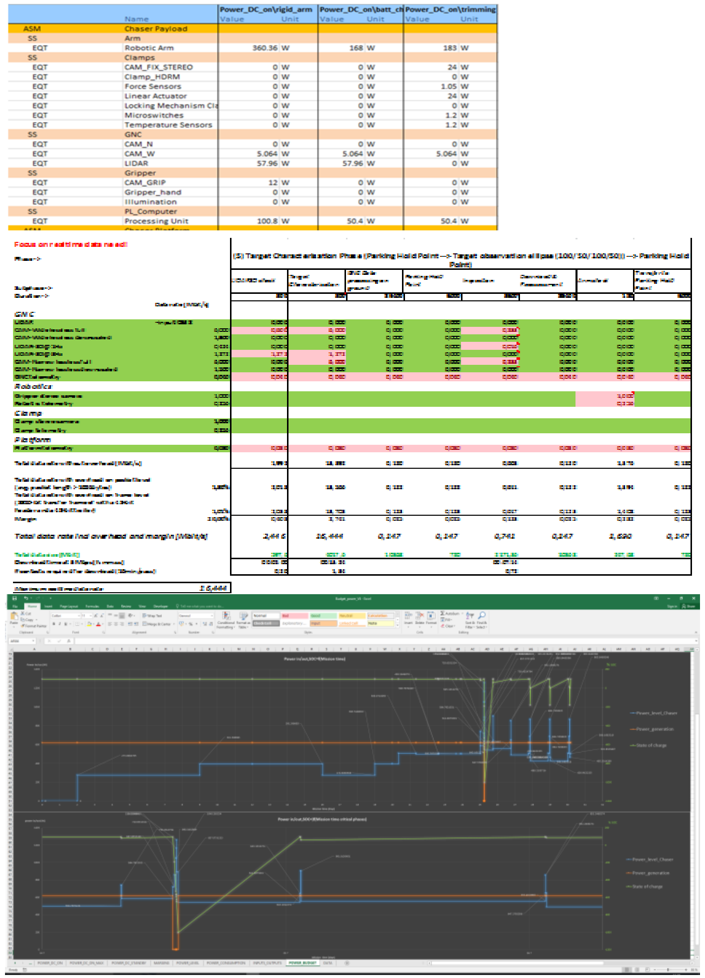
Functional decomposition



Physical decomposition



System budgets



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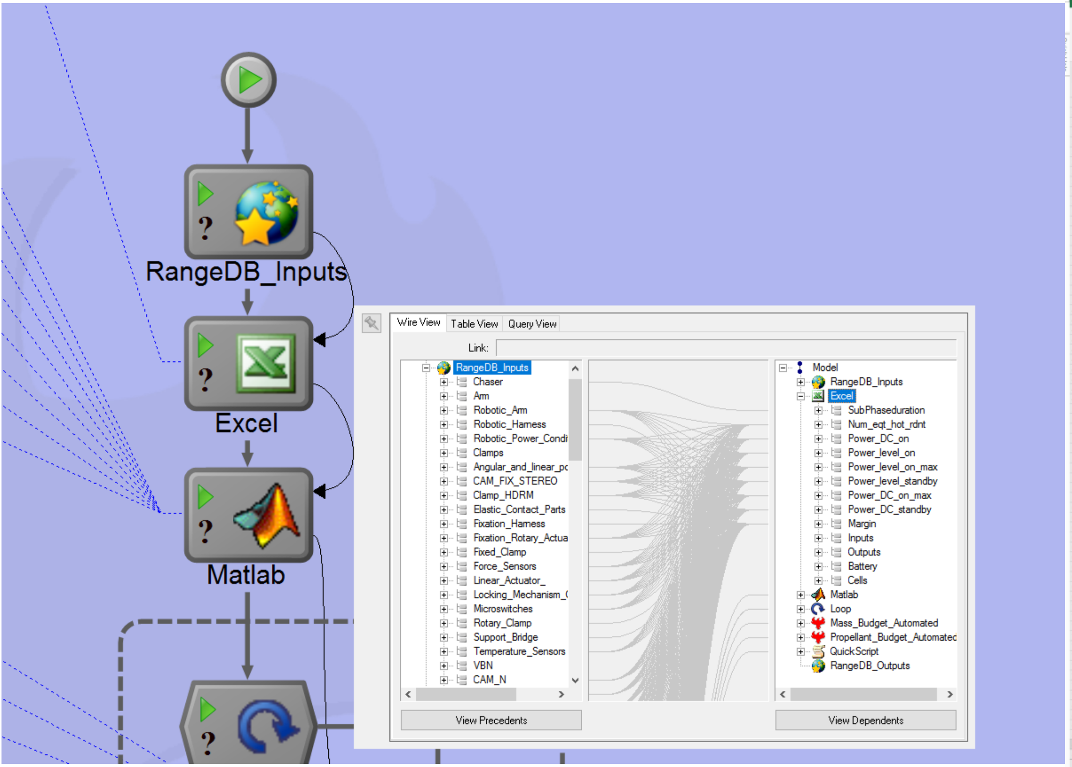
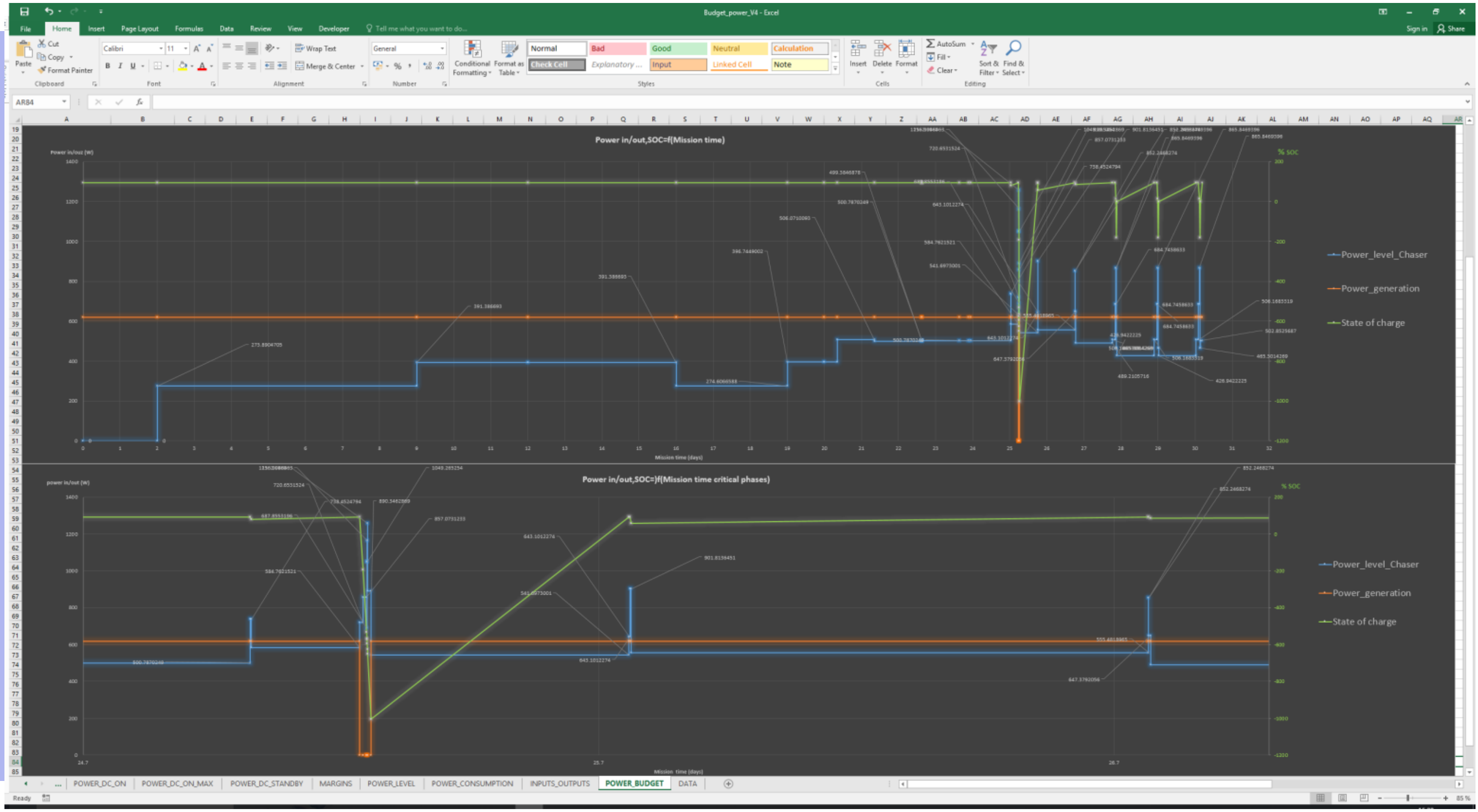
System budgets and system sizing in RangeDB + ModelCenter

Automation and reuse of analysis flows in ModelCenter

Analysis flow in ModelCenter



Power / Energy budget



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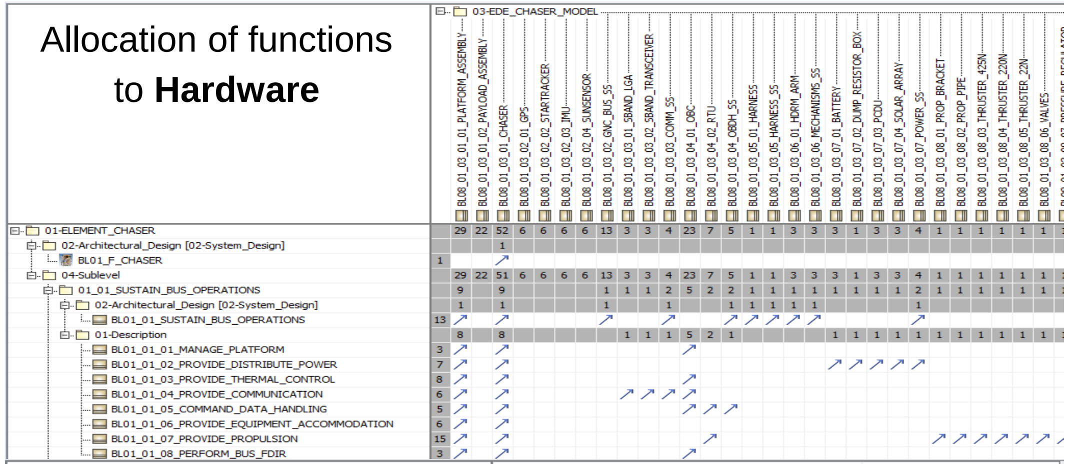
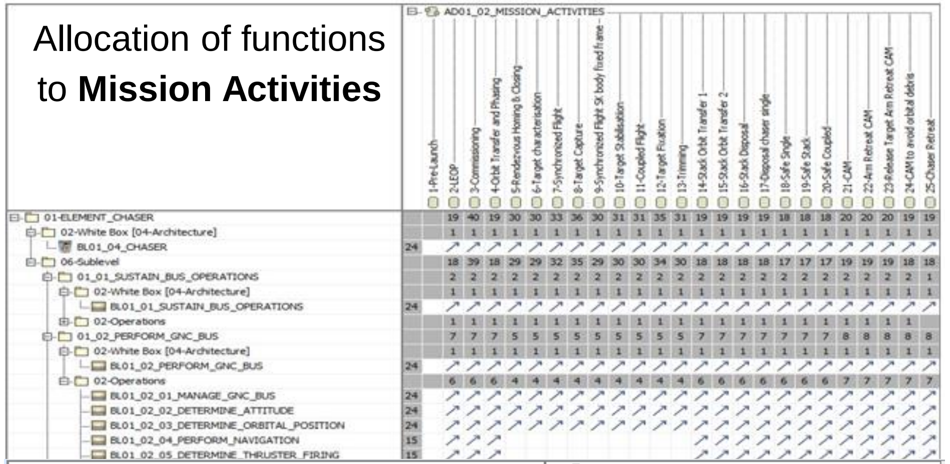
System inter-relation description through functional allocations

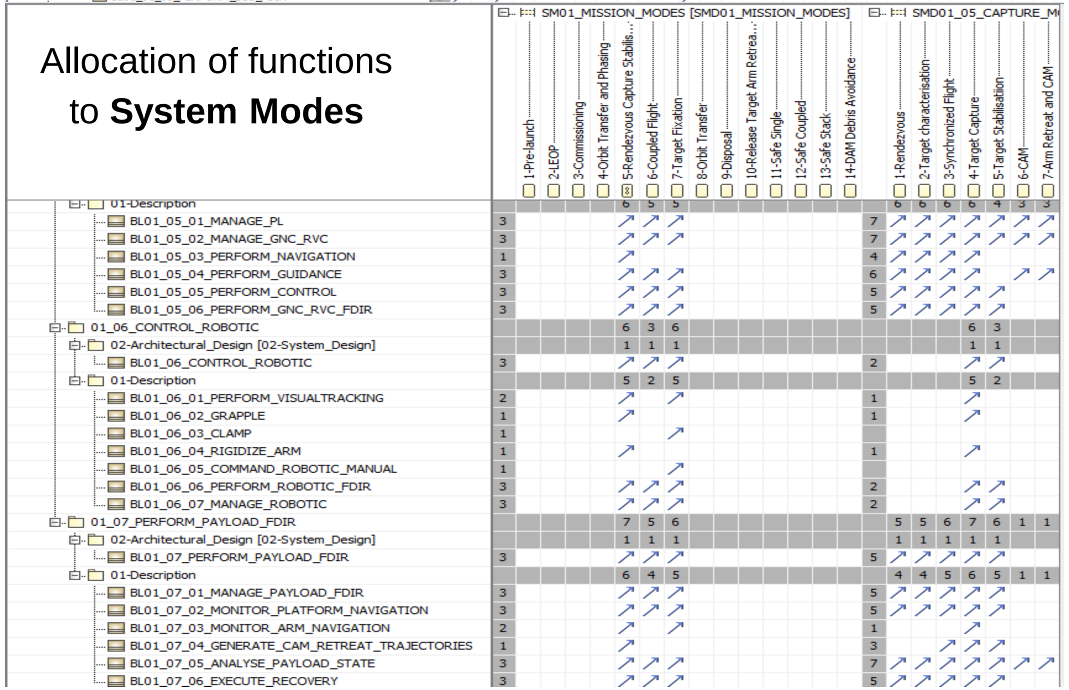
Allocation of functions to **Hardware**



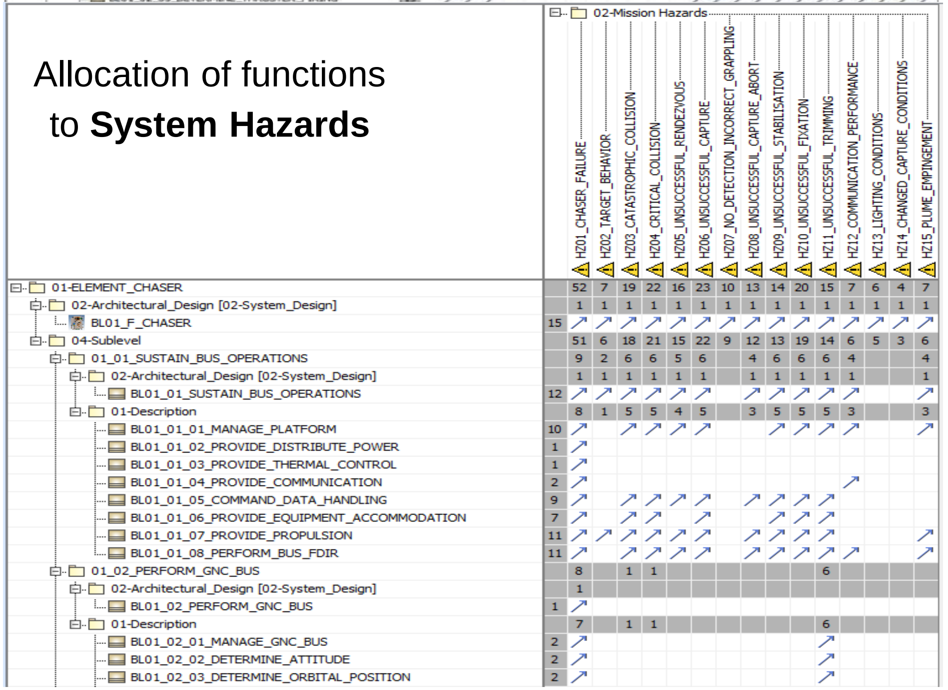
Allocation of functions to **Mission Activities**



Allocation of functions to **System Modes**

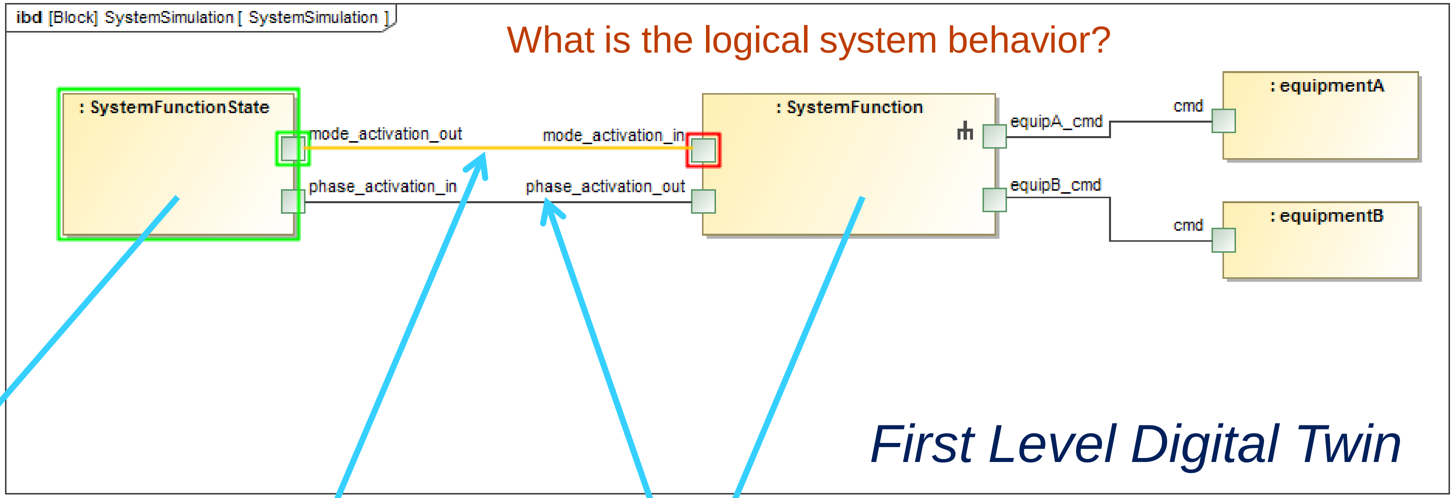


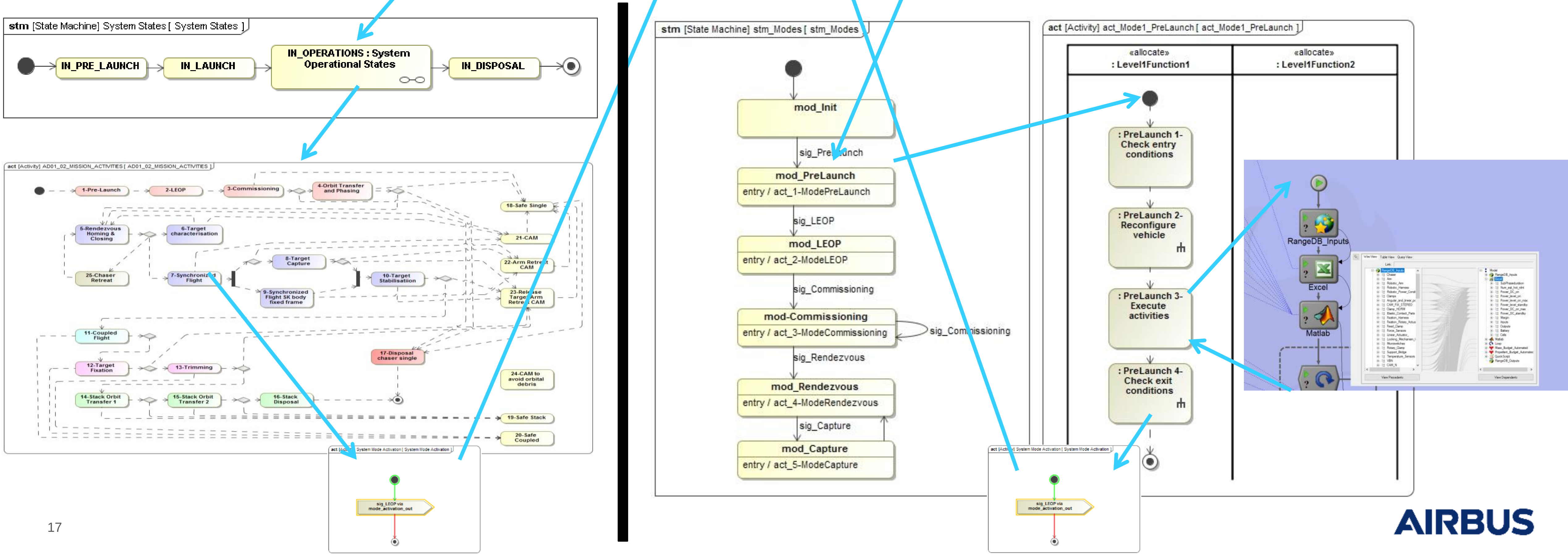
Allocation of functions to **System Hazards**



Model Execution

System data are processed in ModelCenter from the system modes





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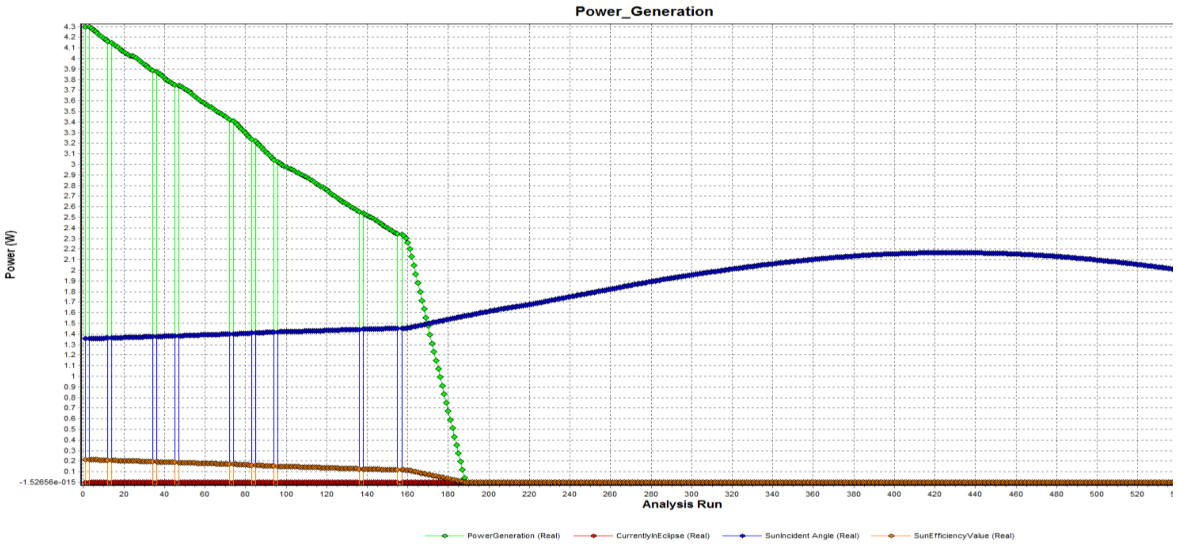
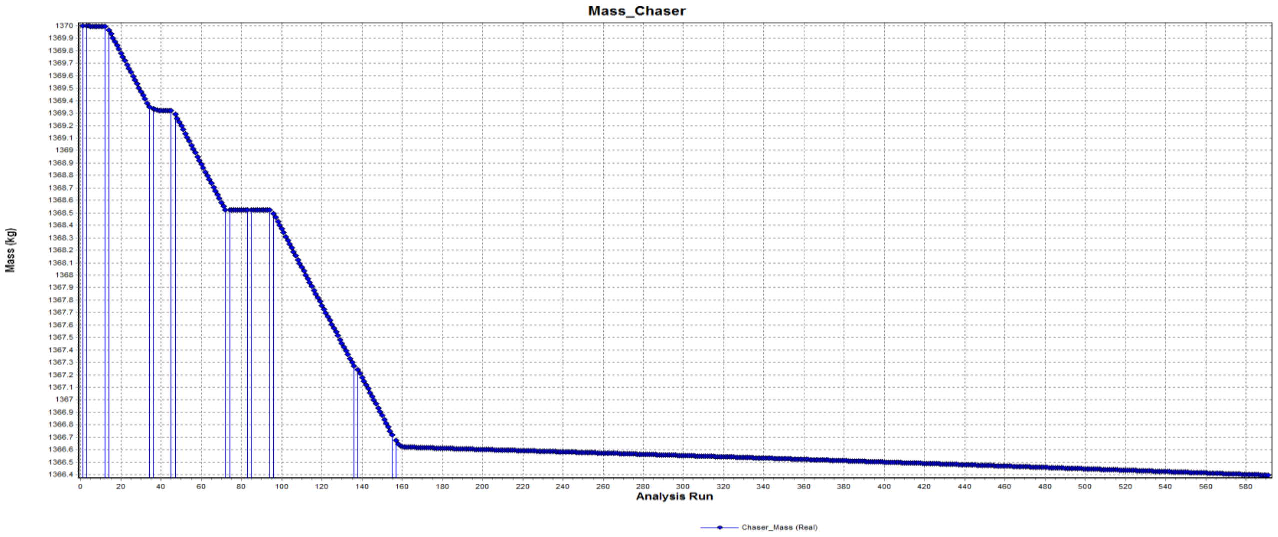
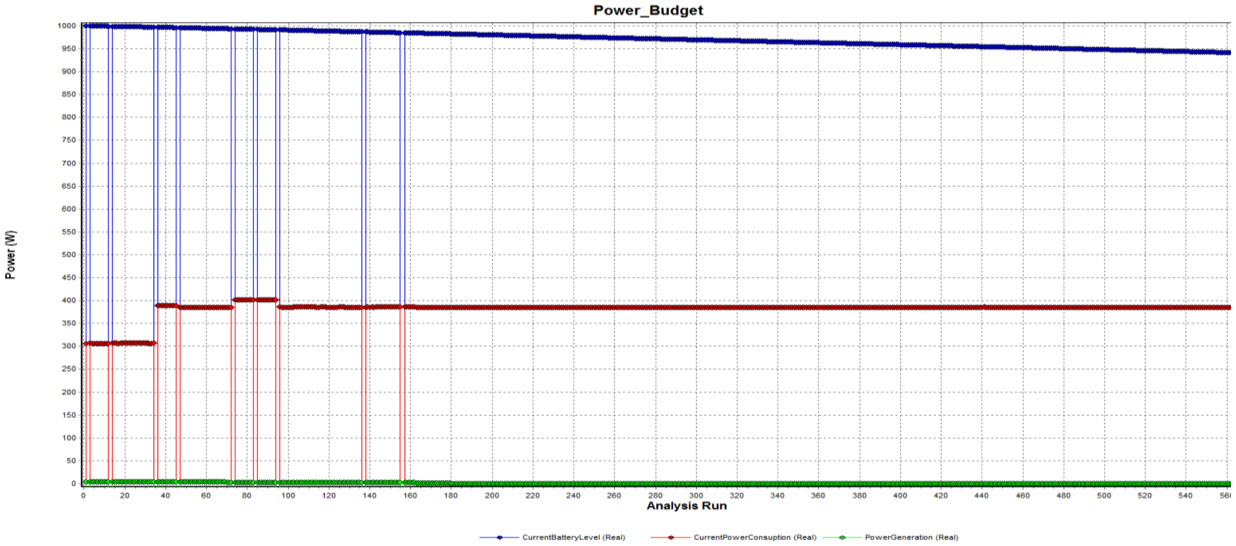
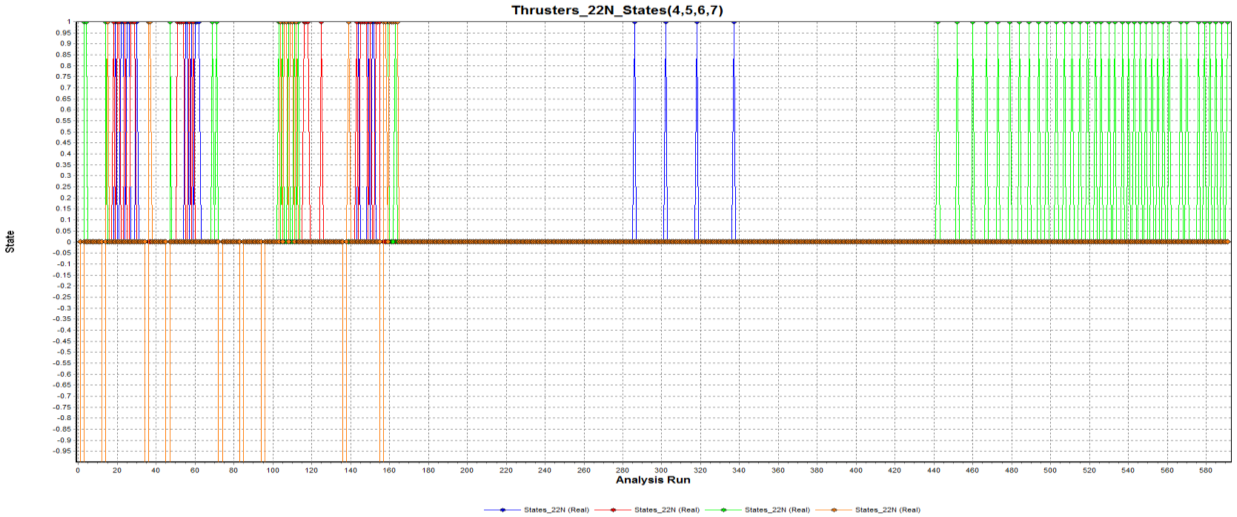
Model execution for getting system responses in various mission scenarios







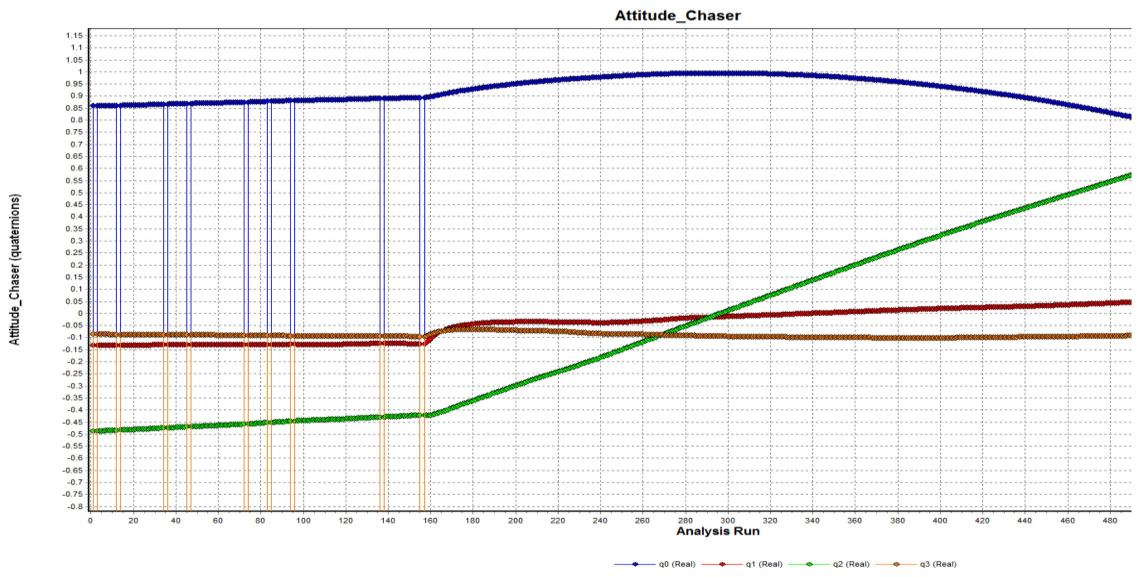


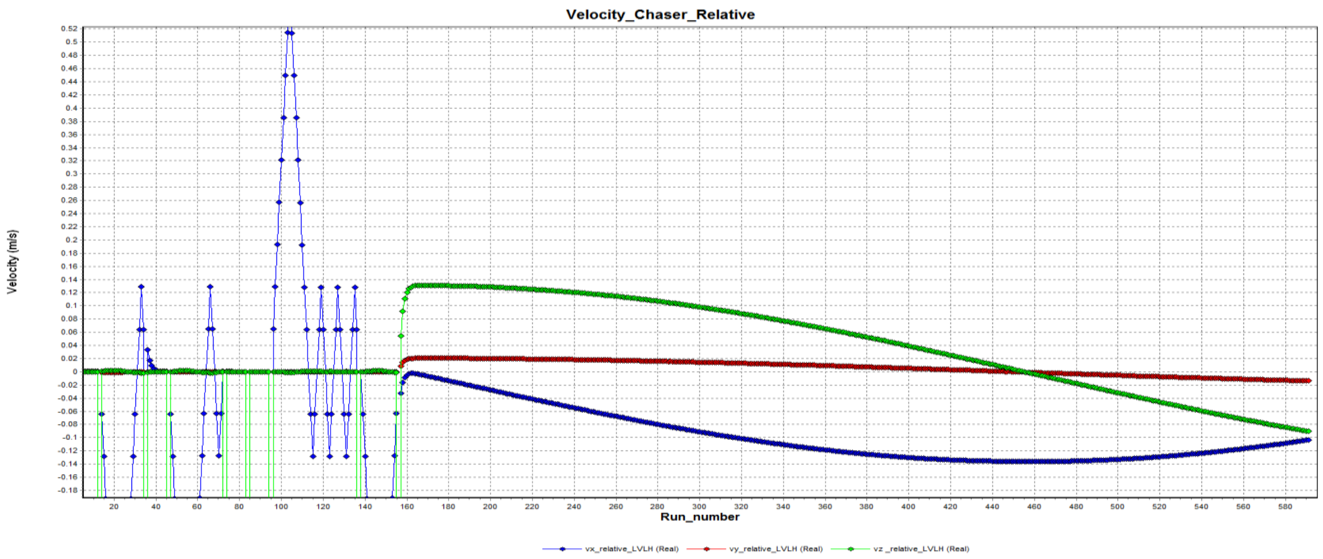
What is the system sensitivity?   Are performance requirements fullfilled, with which margins?

Data exploration based on system response simulations

Check of requirements according to system performance

- Analysis of the system responses for different domains in the same mission context.
- Sensitivity analysis of the system w.r.t. environment changes.
- Check if the performance requirements are always fulfilled for different mission scenarios (regression test).
- Control of the margins on the performances defined in the requirements.
- Optimisation of equipment selection (e.g. analysis of Performance vs. Mass/Cost for single equipment).





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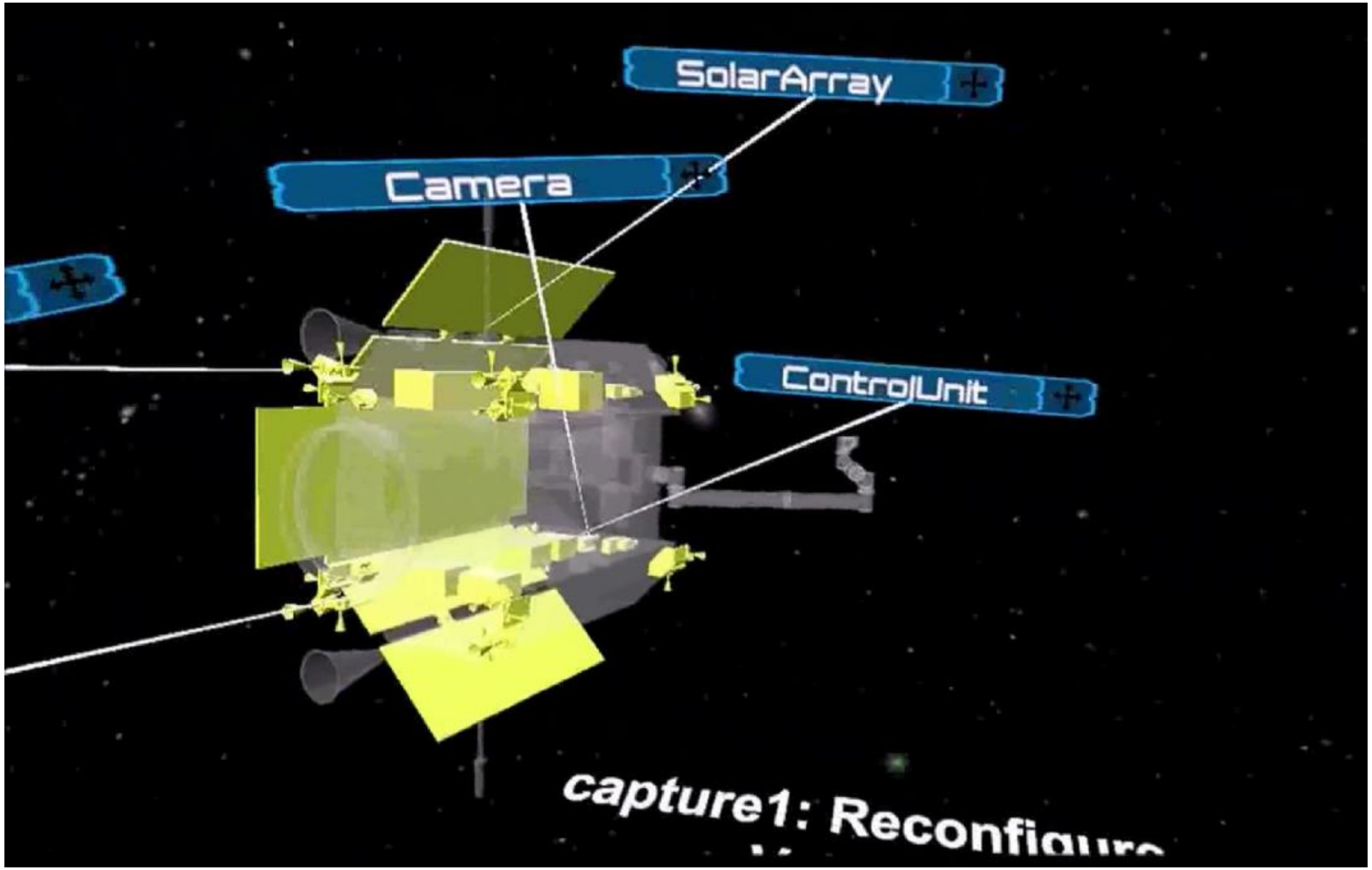
System synthesis in an integrated VR environment

Synthesis of the model data in one digital twin environment

- Provide real time access to MBSE specification and product data (enable ad hoc reviews)

- Provide global view on functional system specification:
  → “walk through” mission phases, system modes, equipment states for each function level

- Vision: provide intent-based user interaction methods to allow fast response to complex questions on engineering data



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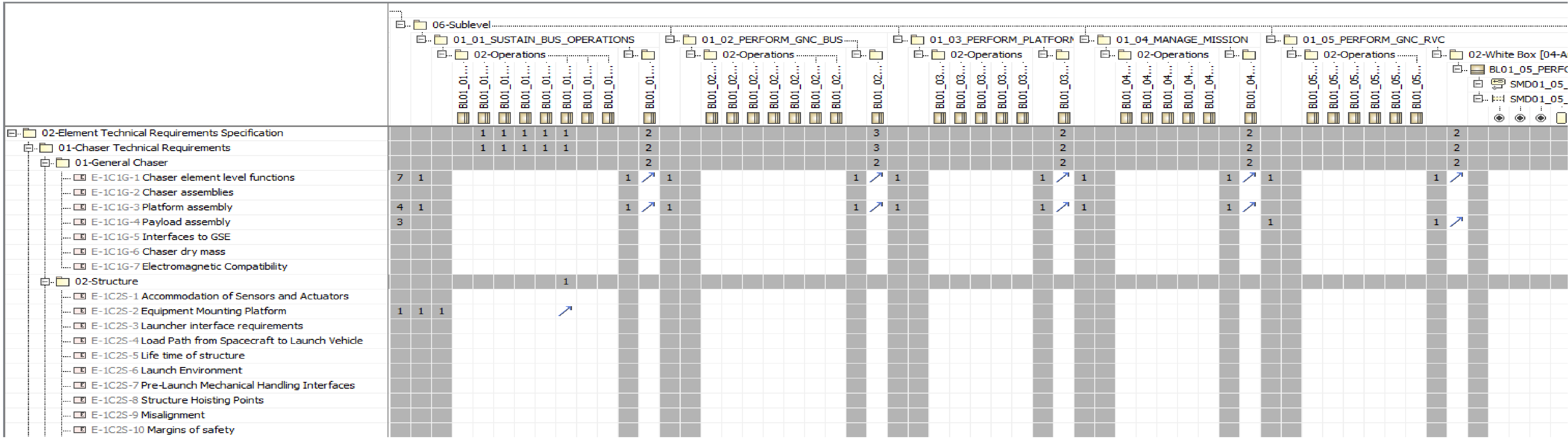
Transformation of models into requirements

Mapping of requirements to the model architectures with the ‘Satisfied by’ relationship



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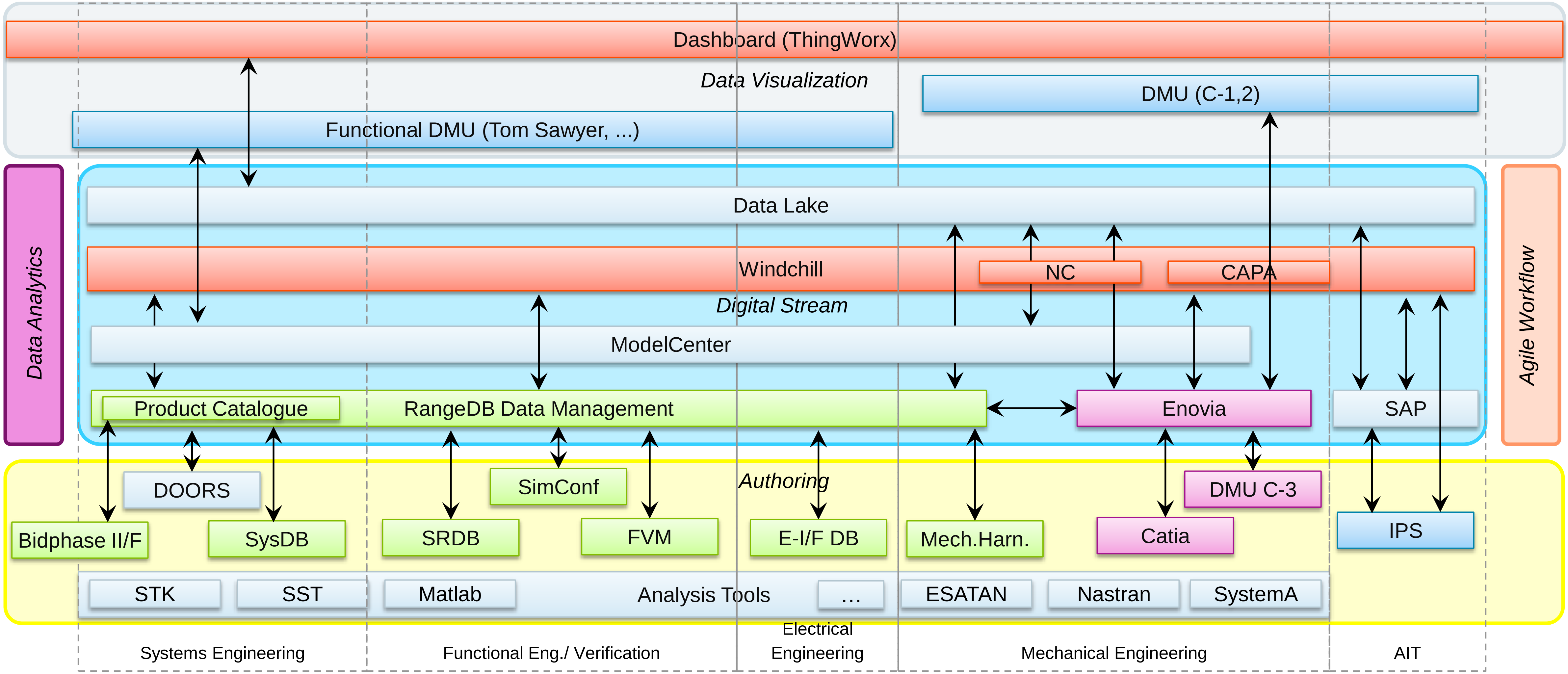
Benefits from modelling and simulating a system in the formulation phase

- To define coherent architectures (functional, physical, control, …)
- To manage the system complexity (scenario, dependencies, interfaces, behavior, responses)
- To generate budgets and validate them in various scenarios wrt requirements
- To validate the architectures w.r.t. properties in analyses and simulations
- To generate complete and consistent set of requirements
- To flow down the system definition to the disciplines
- To perform change impact analysis with the models
- To support the maintenance / evolution of complex systems
- To reduce the development risks with the use of consistent data for the different system analyses
- To automate generation of documentation from the models
- To support collaborative work for the engineering teams

E2E-PLM - Architecture for tools supporting system design at Airbus D&S



Toward increased engineering work efficiency with MBSE

4 main aspects of the MBSE process need further consideration:

1. Solve bottlenecks in data continuity ➡ Collect and share data
2. Reuse data and processes ➡ Develop libraries
3. Automate the processing of data ➡ Prepare data for processing
4. Experiment early with the system ➡ Synthesize and execute models