

A high-resolution photograph of Earth from space, showing the curvature of the planet and the thin blue atmosphere. The surface is dark blue with visible cloud patterns and some illuminated landmasses. The sun is visible on the horizon, creating a bright glow.

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

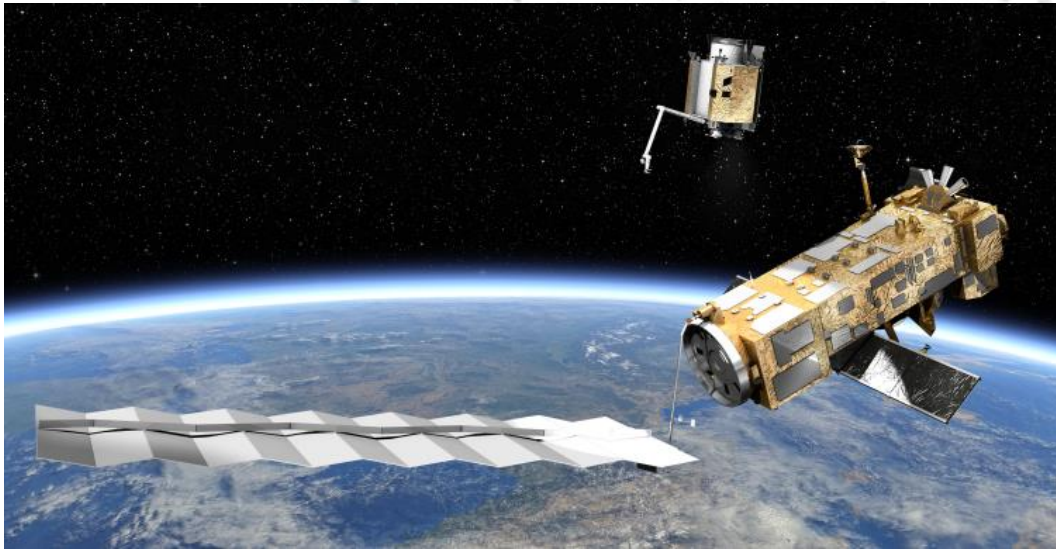
Phoenix Integration
2018 International Users' Conference
April 17-19, 2018
Annapolis, Maryland, USA

DEFENCE AND SPACE

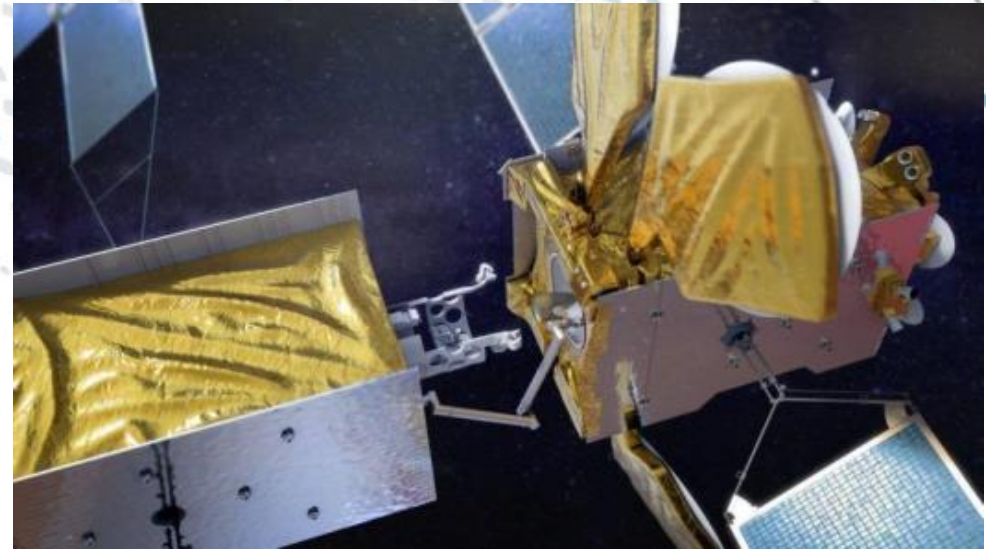
Dr. Stéphane Estable

AIRBUS

Airbus Orbital Servicing Missions



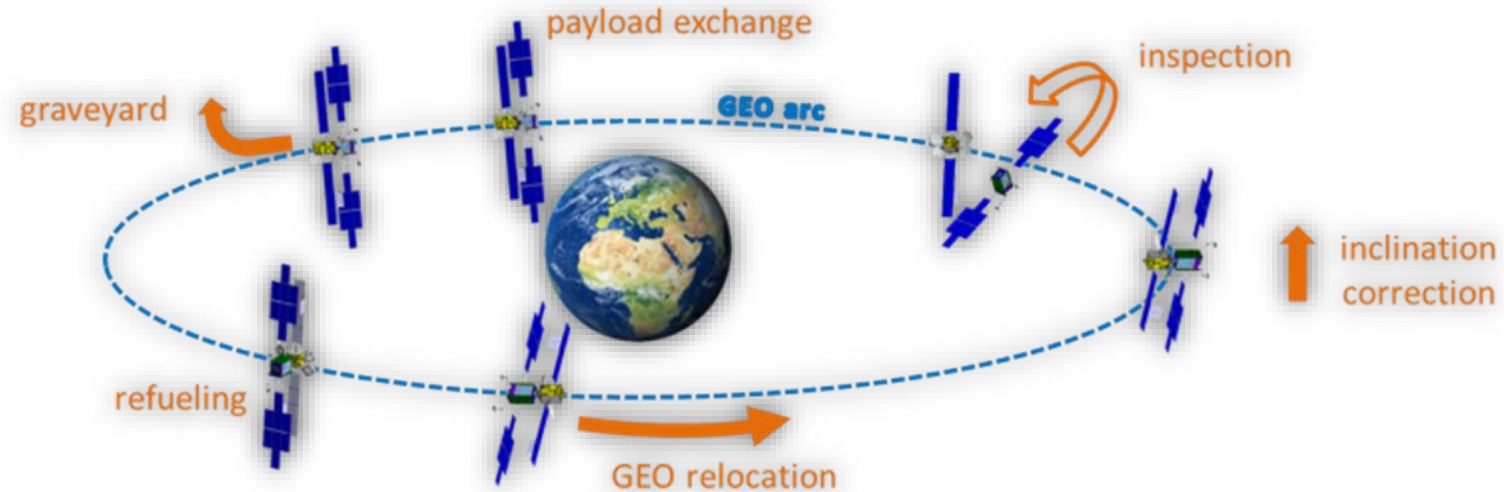
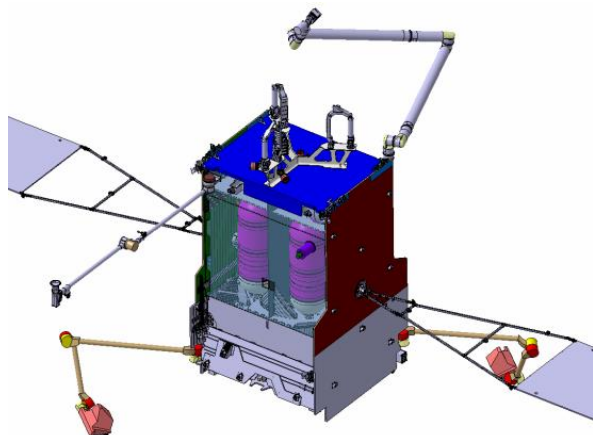
Active Debris Removal



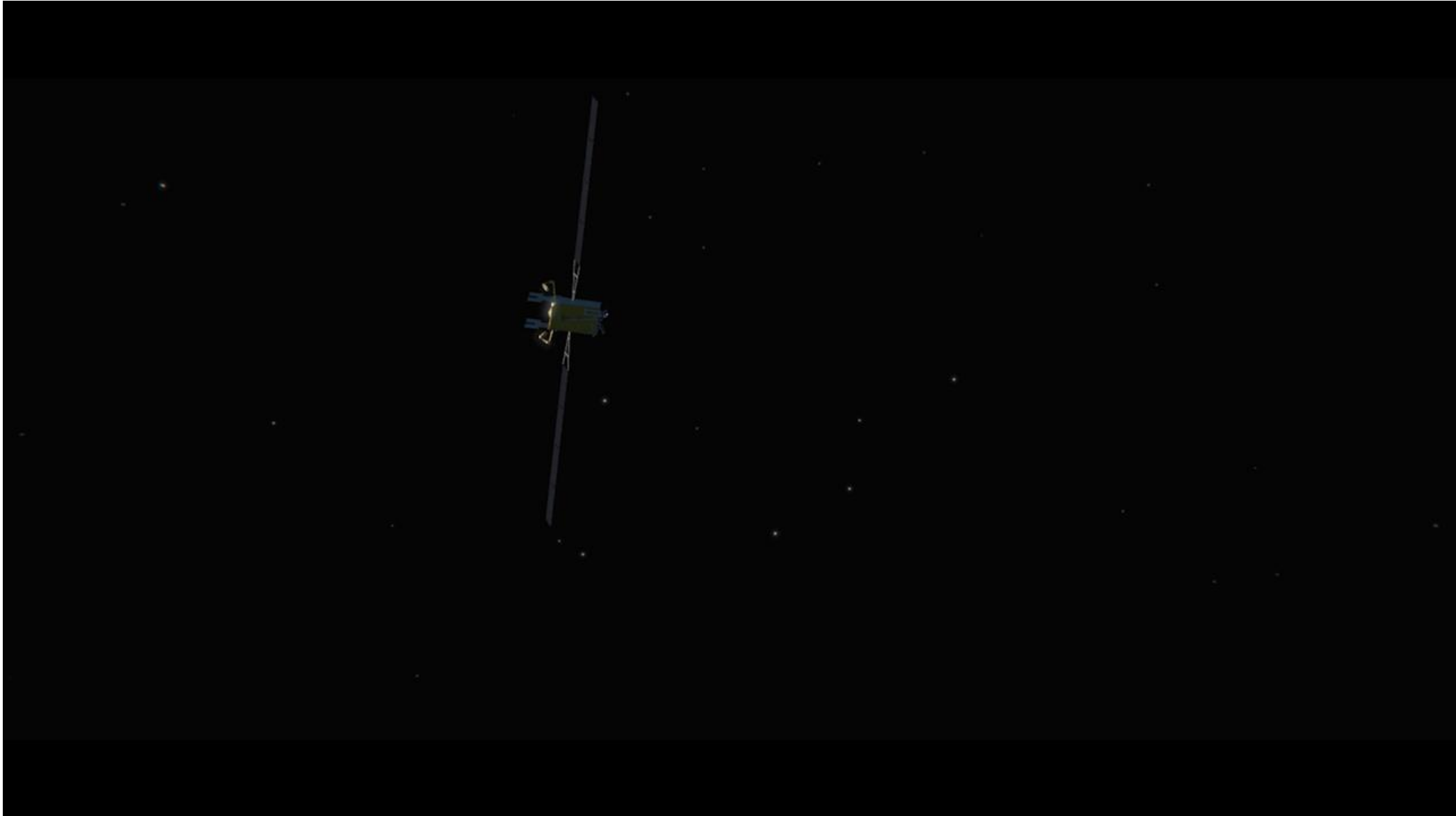
Space Tug Geo-Servicing

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

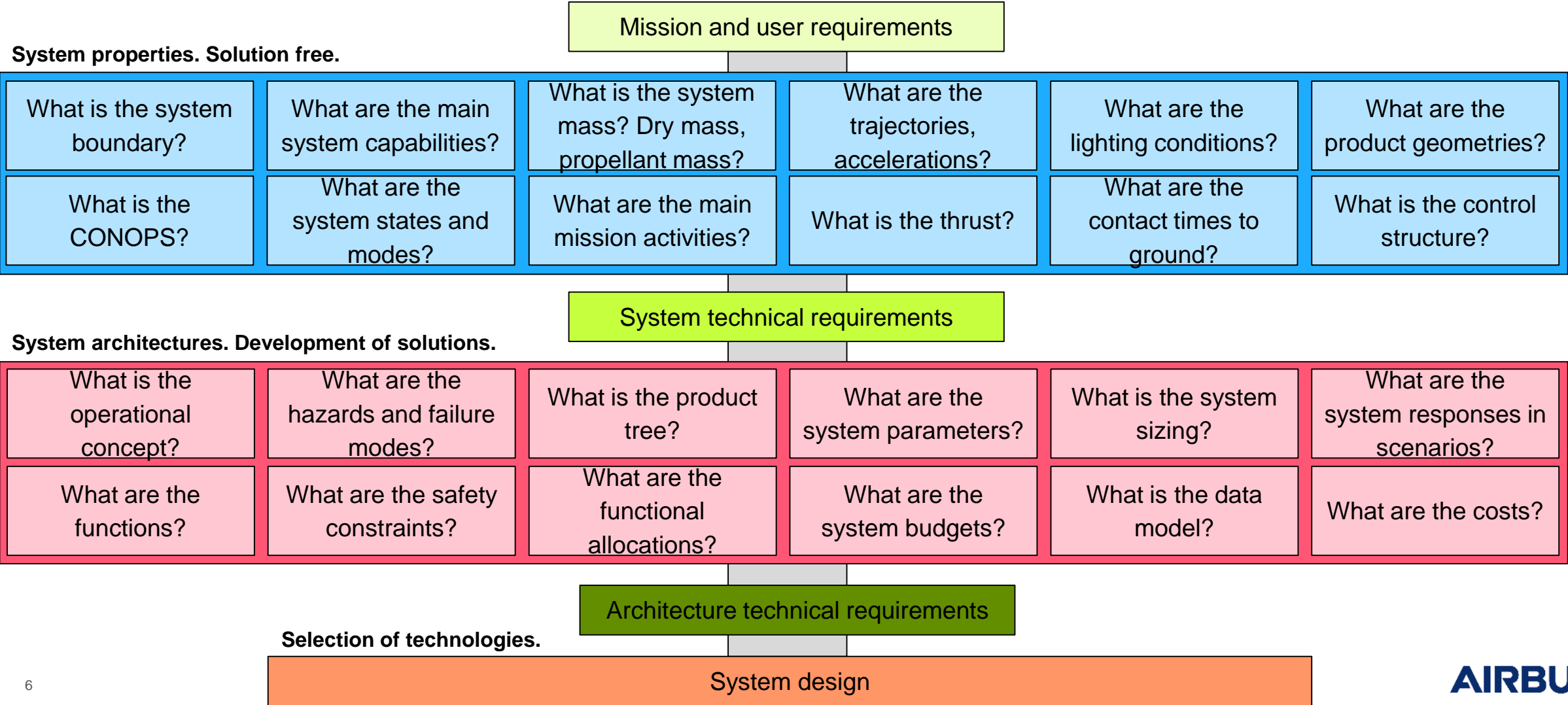


Objectives and definition of the MBSE process 'Federated and Executable Models'

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

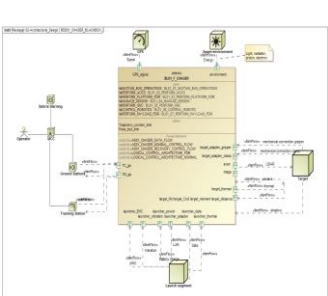


Main data models of the process and data flow

Logical Model Cameo SysML

Describe logical
prop. & architectures

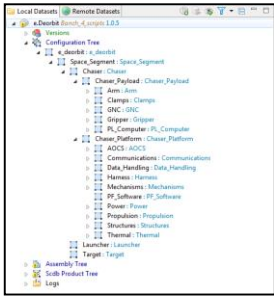
- System capabilities def.
- Mission scenario analysis
- System states and modes
- Functions and Safety
- Architectures



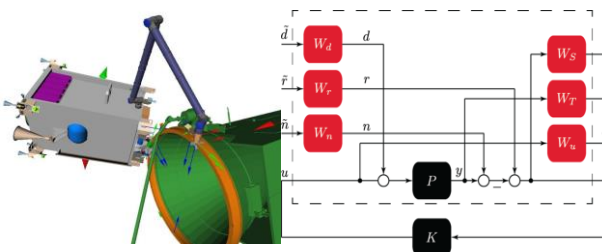
Physical Model RangeDB

Describe physical
prop. & architectures

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



Geometrical / Dynamic Model

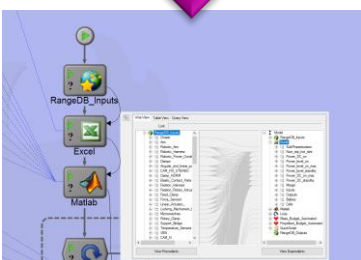


Exchange of model data in standardized data flows

ModelCenter

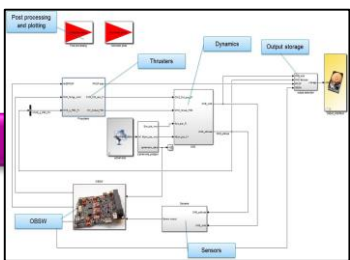
Analyse & Validate
System

- Parameter trends
- Parameter coupling
- Optimisation
- Requirements verification



Analysis Flows

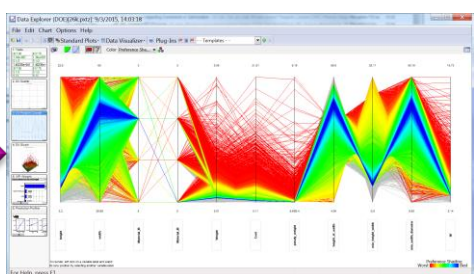
Domain Models



Generate
physical data



Data analysis



Sensitivity, Optimization

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

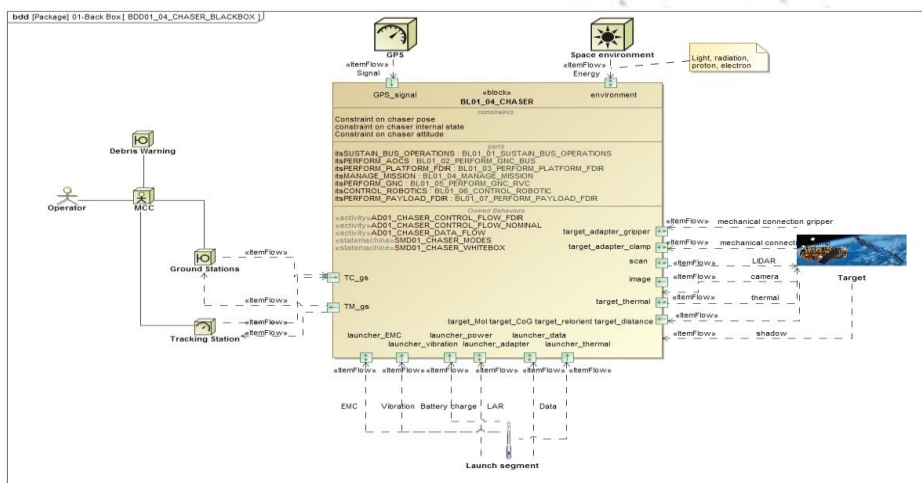
- System boundary and context representation
- Mission representation with states and mission activities
- System representation with capabilities, modes and system activities
- System architectures: functional and physical
- System budgets (mass, propellant, power, energy, data link, data rate, ...)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

Selected tooling environment for the process implementation

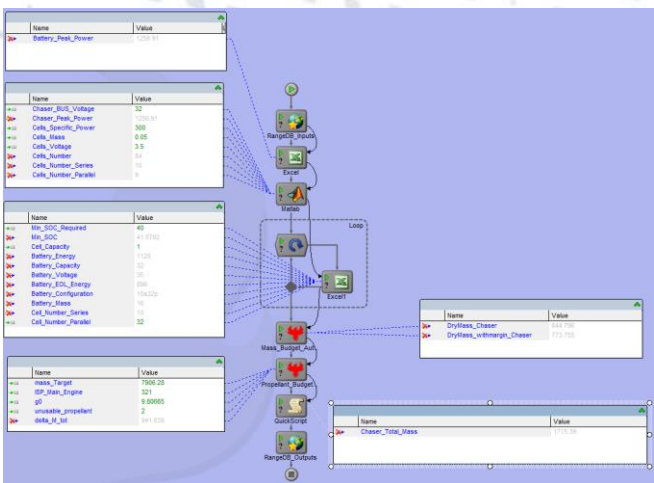
Rely on commercial tools except Airbus DS System Database RangeDB

Data Models	Tools
Physical Model	RangeDB (Airbus)
Logical Model – SysML	Cameo Systems Modeler 18.5 (No Magic)
Analysis Flow for <ul style="list-style-type: none"> • 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)

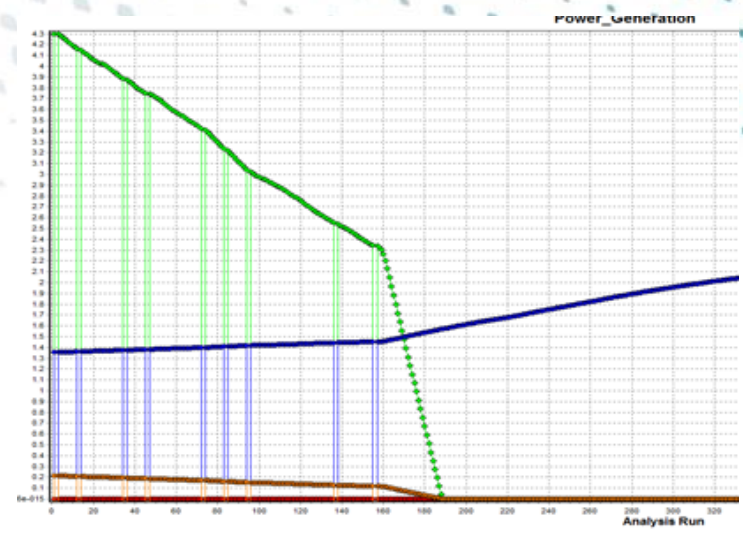
Application of the MBSE process 'Federated and Executable Models'



Descriptive models



Inter-operability of model federation

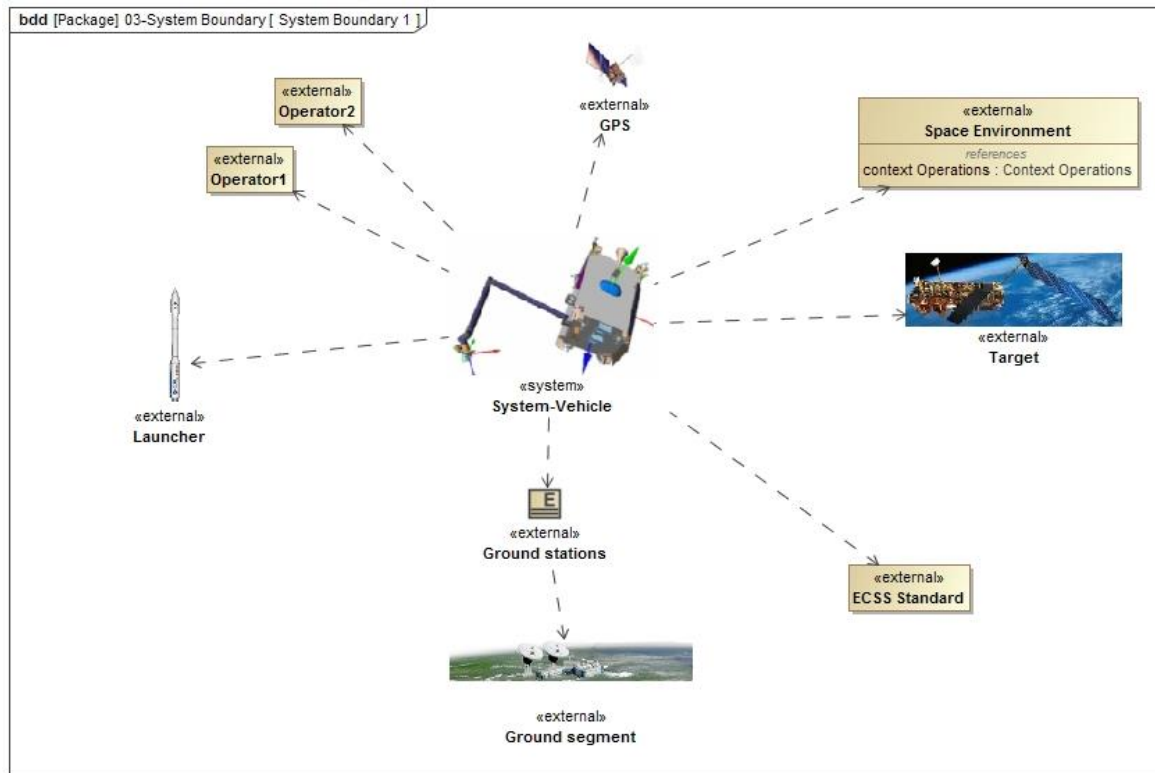


Model execution

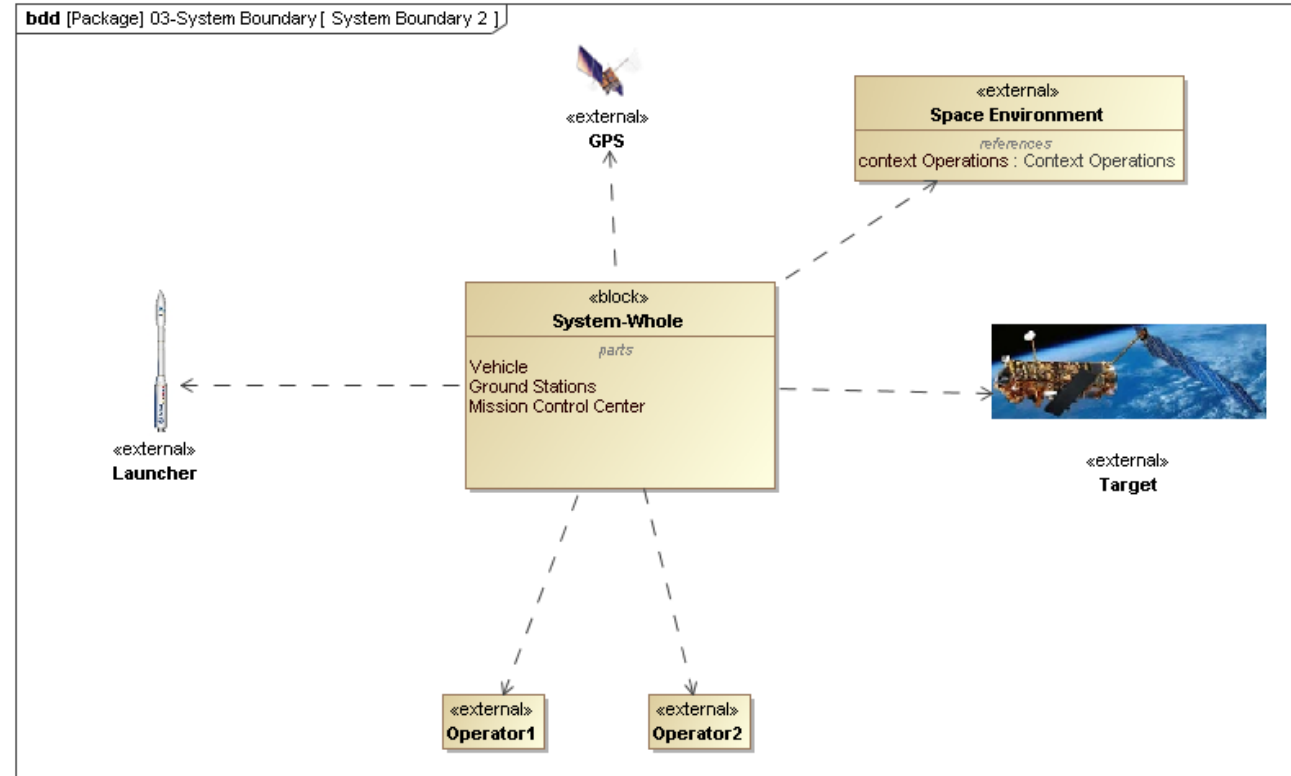
System boundary and stakeholders

Definition of the system of interest and its context

Boundary Solution 1

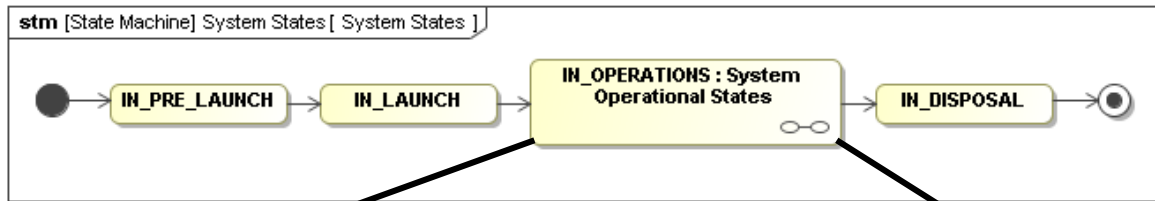


Boundary Solution 2

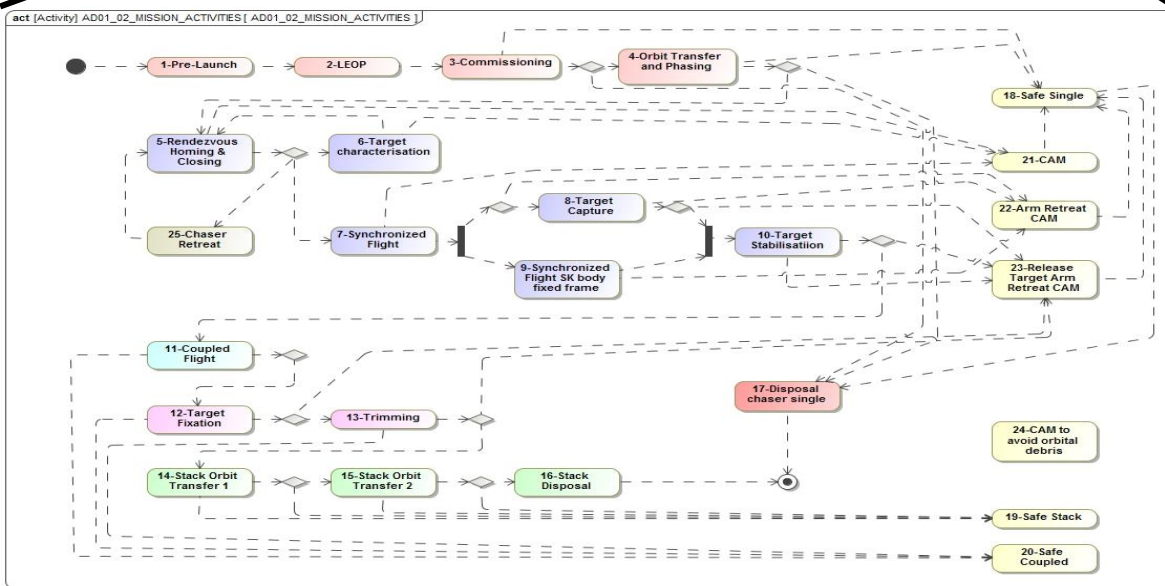


Mission activities and System capabilities

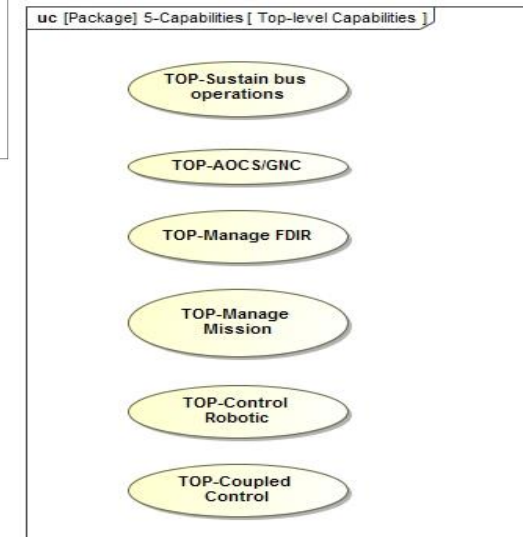
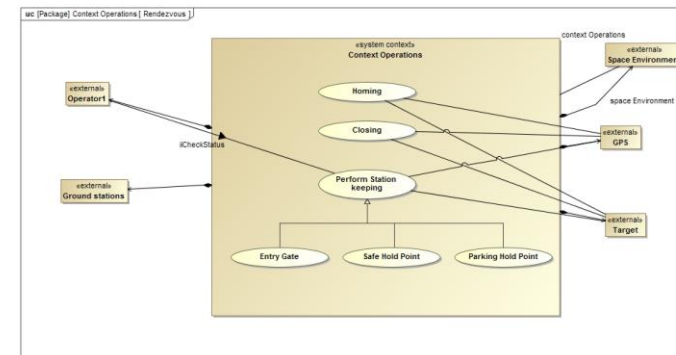
System states



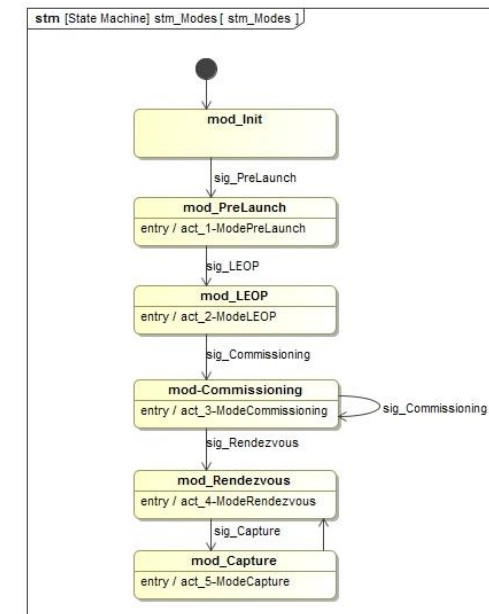
Mission phases and activities



System capabilities (no functions at this stage)



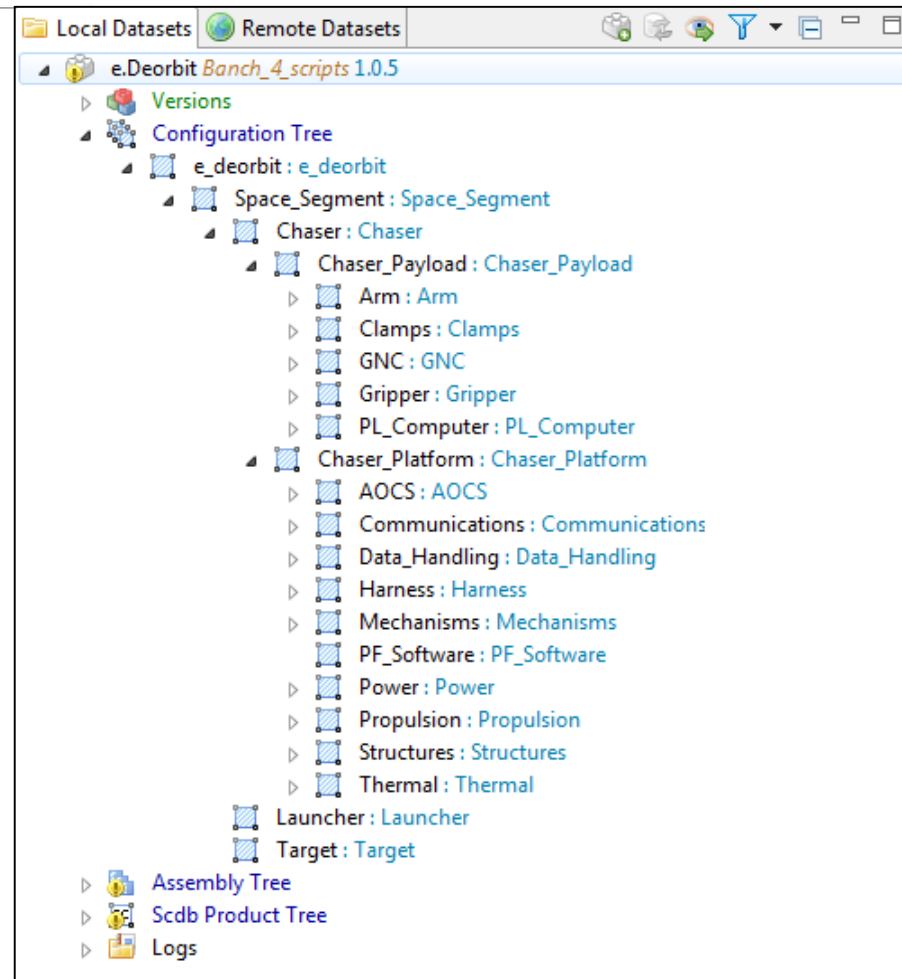
System modes



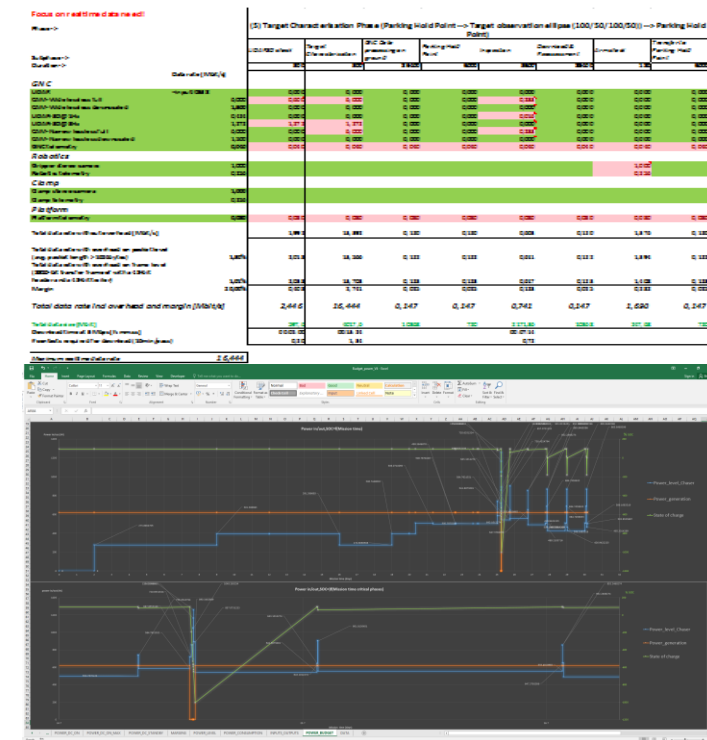
Functional decomposition

Physical decomposition

System budgets



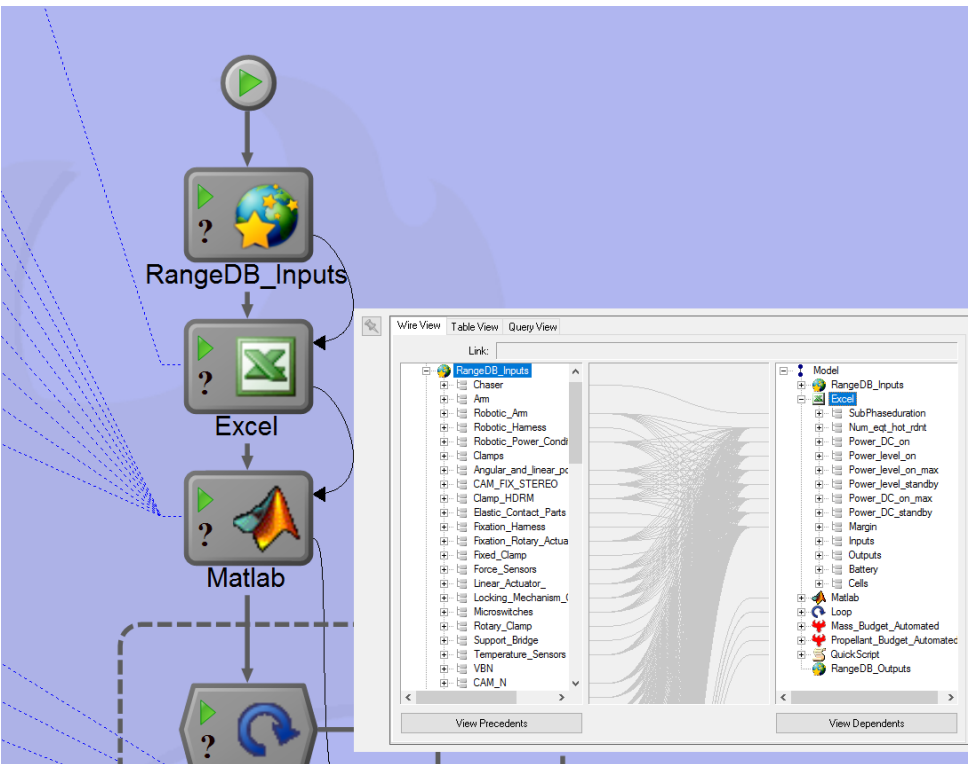
ASIM	Device	Power_DC_on/valid_arm		Power_DC_on/bat		Power_DC_on/trimming	
		Value	Unit	Value	Unit	Value	Unit
S5	Chassis Payload						
	Arm						
	Robotic Arm	360.36	W	268	W	183	W
	Clamps						
	CAM_FIX_STEREO	0	W	0	W	24	W
	Clamp_HDMI	0	W	0	W	24	W
	Force Sensors	0	W	0	W	1.05	W
	Linear Actuator	0	W	0	W	1.2	W
	Locking Mechanism Ch	0	W	0	W	0	W
	Microphones	0	W	0	W	1.2	W
S5	Temperature Sensors	0	W	0	W	0	W
	GNC	0	W	0	W	0	W
	CAM_N	0	W	0	W	0	W
	LDAM	5.064	W	5.064	W	5.064	W
	CAM_D	57.96	W	57.96	W	0	W
	Gripper						
	CAM_GRIP	32	W	0	W	0	W
	Gripper_hand	0	W	0	W	0	W
	Illumination	0	W	0	W	0	W
	FLController						
S5	Processing Unit	100.8	W	50.4	W	50.4	W



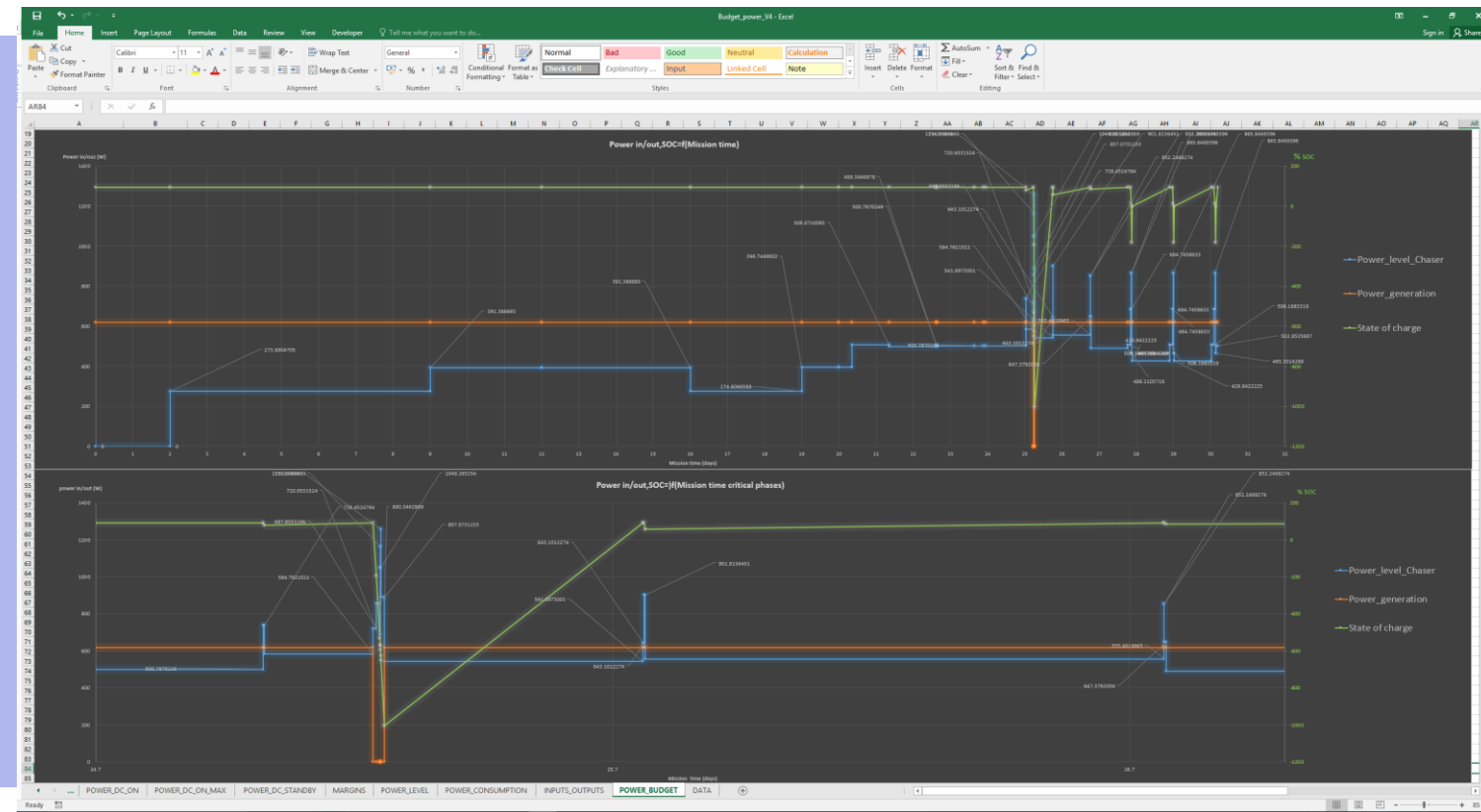
System budgets and system sizing in RangeDB + ModelCenter

Automation and reuse of analysis flows in ModelCenter

Analysis flow in ModelCenter



Power / Energy budget



System inter-relation description through functional allocations

Allocation of functions to Hardware	
<ul style="list-style-type: none"> 01-ELEMENT_CHASER <ul style="list-style-type: none"> 02-Architectural_Design [02-System_Design] <ul style="list-style-type: none"> BL01_F_CHASER <ul style="list-style-type: none"> 04-Sublevel <ul style="list-style-type: none"> 01_01_SUSTAIN_BUS_OPERATIONS <ul style="list-style-type: none"> 02-Architectural_Design [02-System_Design] <ul style="list-style-type: none"> 01-Description <ul style="list-style-type: none"> BL01_01_01_MANAGE_PLATFORM BL01_01_02_PROVIDE_DISTRIBUTE_POWER BL01_01_03_PROVIDE_THERMAL_CONTROL BL01_01_04_PROVIDE_COMMUNICATION BL01_01_05_COMMAND_DATA_HANDLING BL01_01_06_PROVIDE_EQUIPMENT_ACCOMMODATION BL01_01_07_PROVIDE_PROPULSION BL01_01_08_PERFORM_BUS_FDIR 	<ul style="list-style-type: none"> 03-ED-CHASER_MODEL <ul style="list-style-type: none"> BL08_01_03_01_01_PLATFORM_ASSEMBLY BL08_01_03_01_02_PAYLOAD_ASSEMBLY BL08_01_03_01_03_CHASER BL08_01_03_01_04_GPS BL08_01_03_01_05_STARTER BL08_01_03_01_06_INU BL08_01_03_01_07_SUNSENSOR BL08_01_03_01_08_GNC_BUS_S5 BL08_01_03_01_09_SEND_LGA BL08_01_03_01_10_SEND_TRANSEIVER BL08_01_03_01_11_COM1_S5 BL08_01_03_01_12_OBC BL08_01_03_01_13_FPU BL08_01_03_01_14_OBC_S5 BL08_01_03_01_15_HARNESS BL08_01_03_01_16_HARNESS_S5 BL08_01_03_01_17_HORN_ARM BL08_01_03_01_18_MECHANISMS_S5 BL08_01_03_01_19_BATTERY BL08_01_03_01_20_DUMP_RESISTOR_BOX BL08_01_03_01_21_PDU BL08_01_03_01_22_SQAR_ARRAY BL08_01_03_01_23_POWER_S5 BL08_01_03_01_24_PROP_BRACKET BL08_01_03_01_25_PROP_PIPE BL08_01_03_01_26_THRUSTER_4SH BL08_01_03_01_27_THRUSTER_20H BL08_01_03_01_28_THRUSTER_20H BL08_01_03_01_29_VALUES

Allocation of functions to Mission Activities	
<ul style="list-style-type: none"> 01-ELEMENT_CHASER <ul style="list-style-type: none"> 02-White Box [04-Architecture] <ul style="list-style-type: none"> BL01_04_CHASER <ul style="list-style-type: none"> 06-Sublevel <ul style="list-style-type: none"> 01_01_SUSTAIN_BUS_OPERATIONS <ul style="list-style-type: none"> 02-White Box [04-Architecture] <ul style="list-style-type: none"> BL01_01_SUSTAIN_BUS_OPERATIONS <ul style="list-style-type: none"> 01-Description <ul style="list-style-type: none"> BL01_01_01_MANAGE_GNC_BUS BL01_01_02_DETERMINE_ATTITUDE BL01_01_03_DETERMINE_ORBITAL_POSITION BL01_01_04_PERFORM_NAVIGATION BL01_01_05_DETERMINE_THRUSTER_FIRING 	<ul style="list-style-type: none"> AD01_02_MISSION_ACTIVITIES <ul style="list-style-type: none"> 1-Pre-launch 2-LEOP 3-Commissioning 4-Orbit Transfer and Phasing 5-Endogenous Homing & Closing 6-Target characterisation 7-Synchronised Flight 8-Target Capture 9-Synchronised Flight SR body fixed frame 10-Target Substitution 11-Coupled Flight 12-Target Fusion 13-Trimming 14-Safe Orbit Transfer 1 15-Safe Orbit Transfer 2 16-Safe Descent 17-Target characterisation 18-Safe Single 19-Safe Coupled 20-Safe Coupled 21-CAN 22-Arm Retreat CAM 23-Release Target Arm Retreat CAM 24-CAN to avoid orbital debris 25-Chaser Retreat

Allocation of functions to System Modes

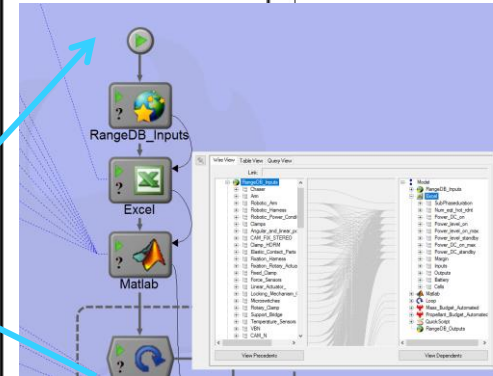
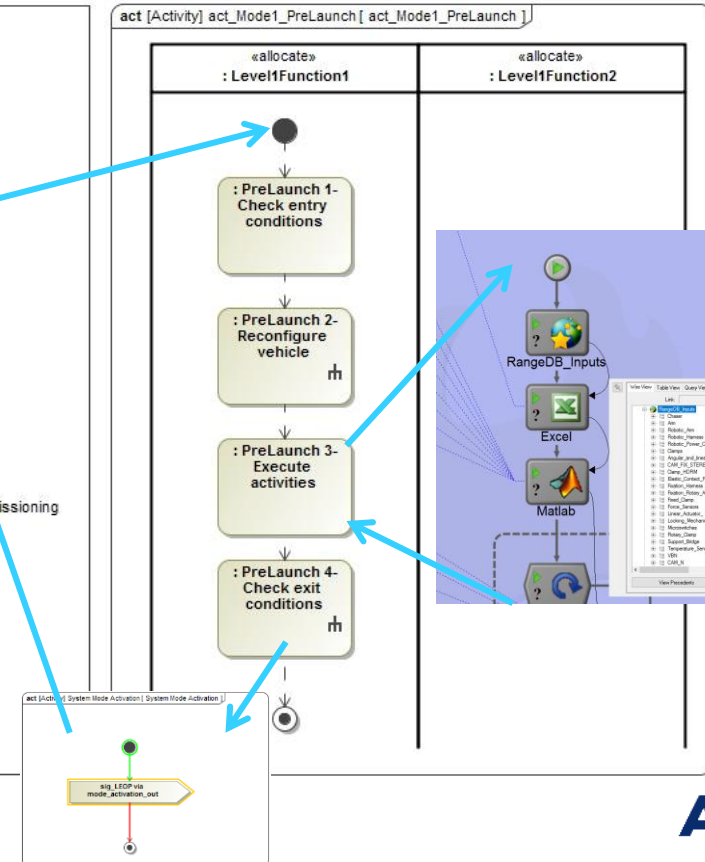
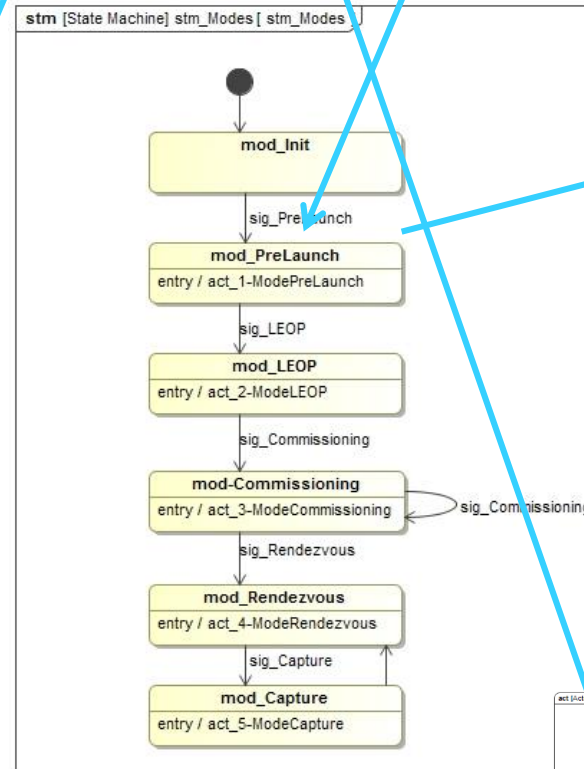
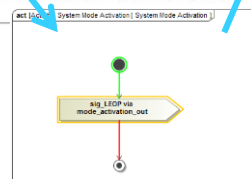
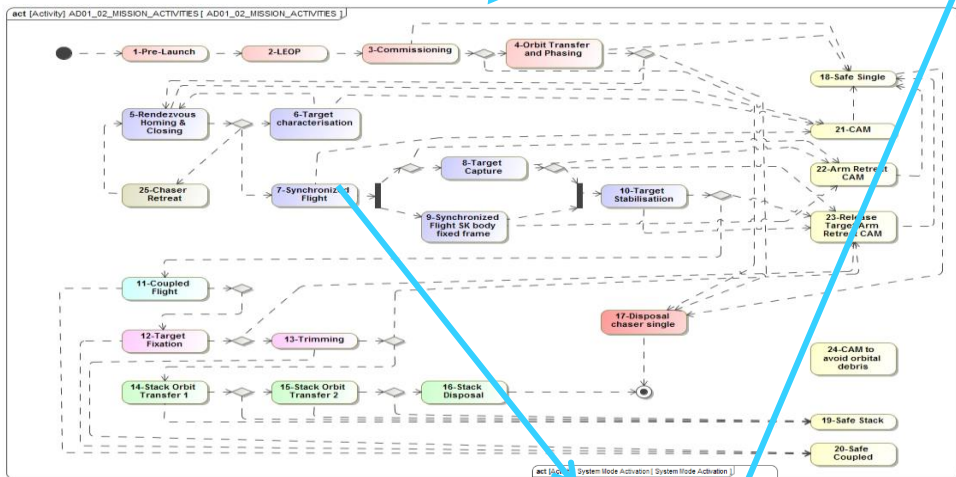
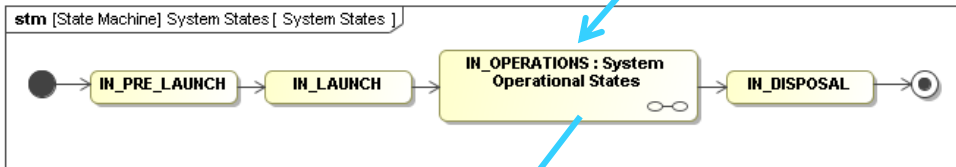
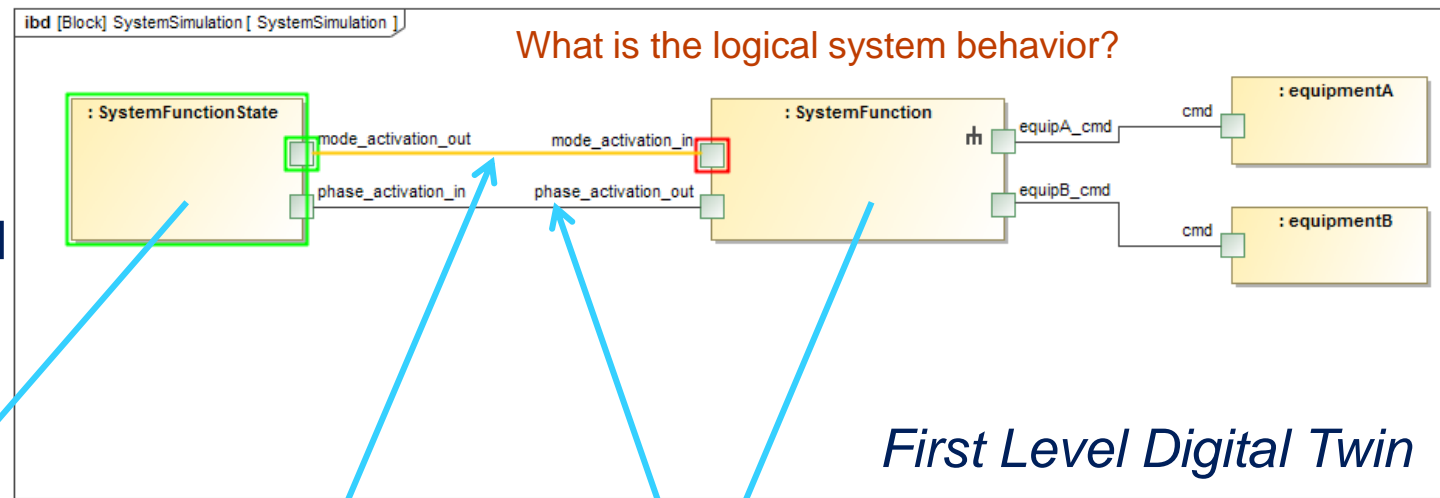
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Allocation of functions to System Hazards

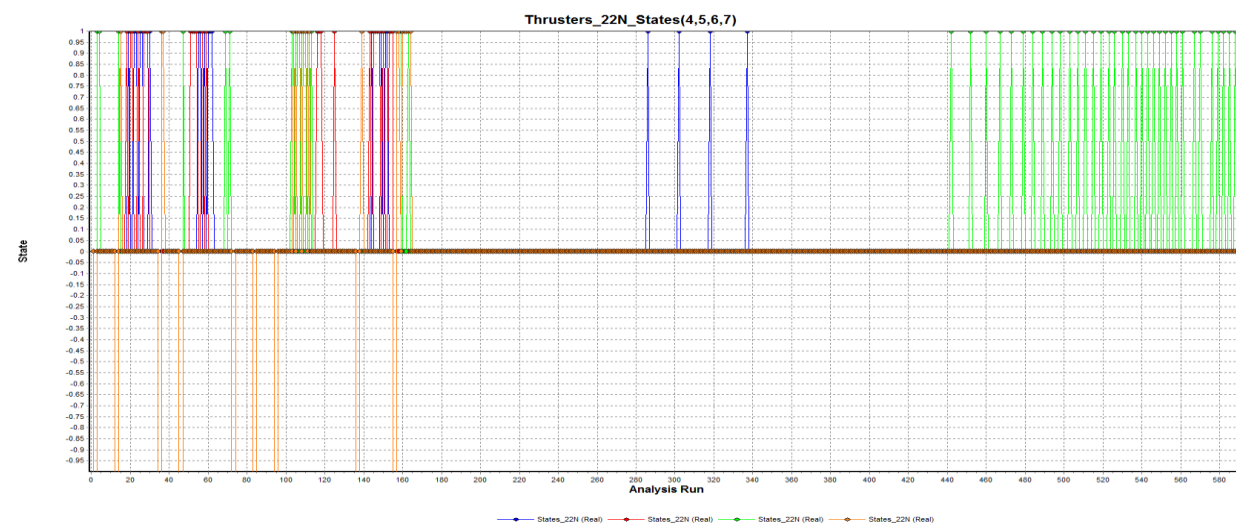
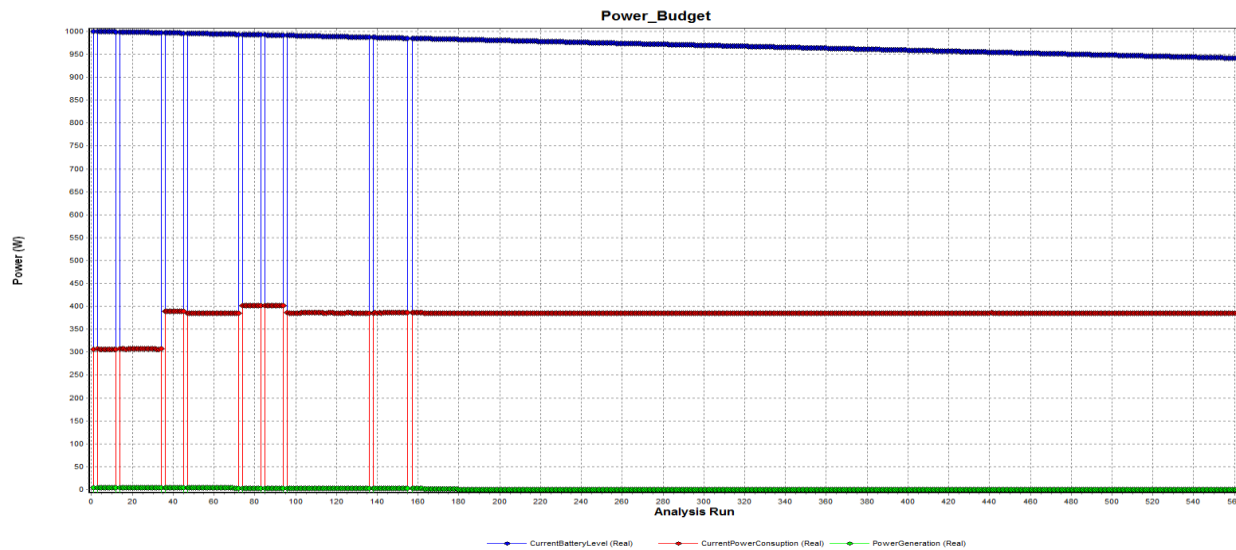
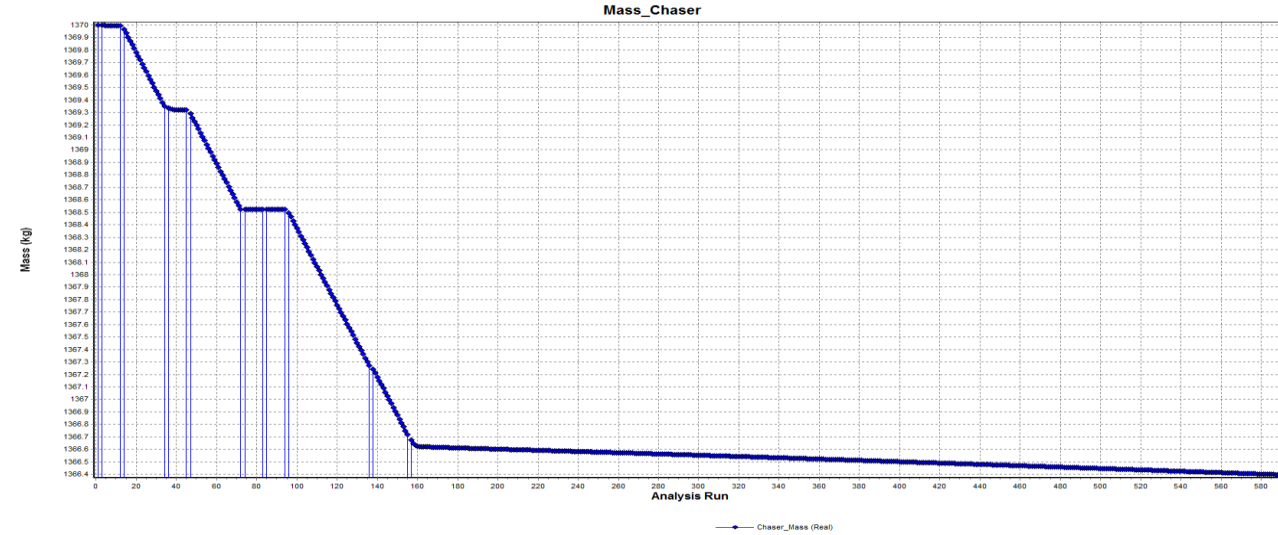
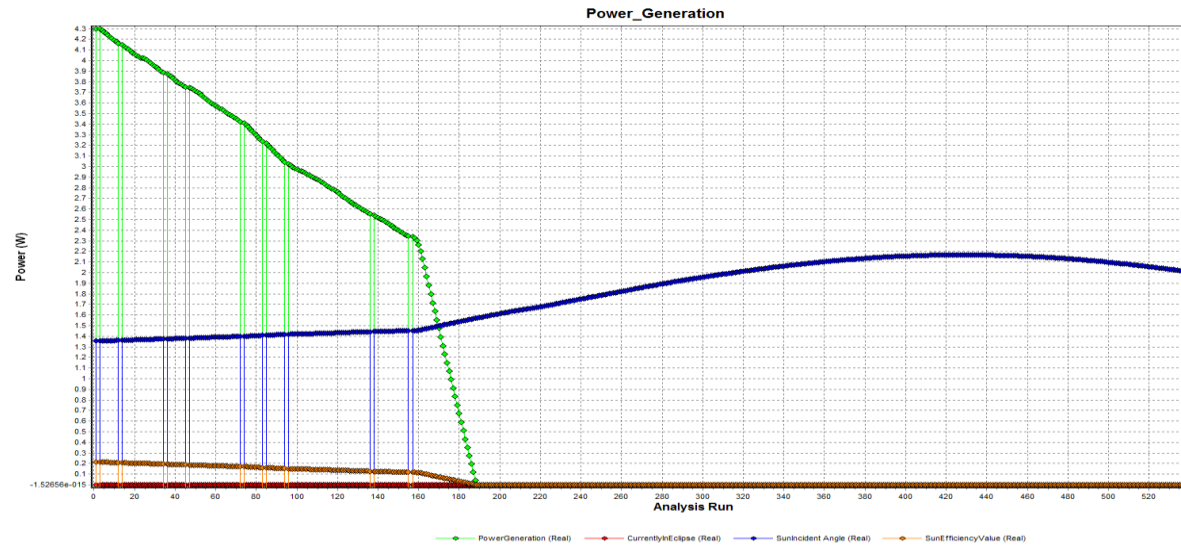
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Model Execution

System data are processed in ModelCenter from the system modes



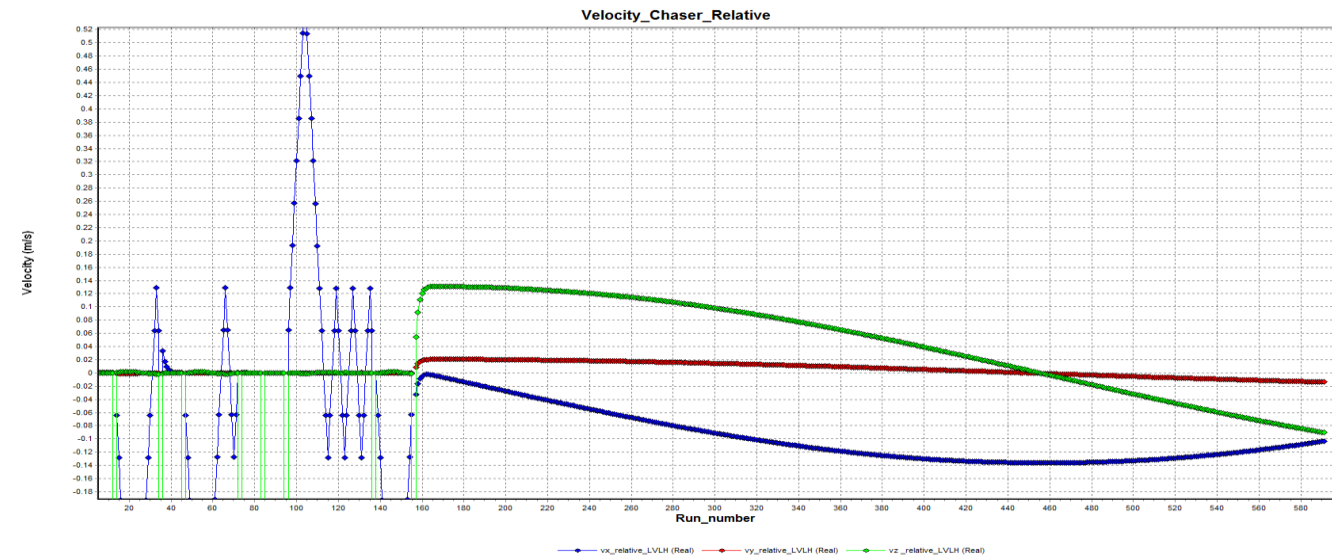
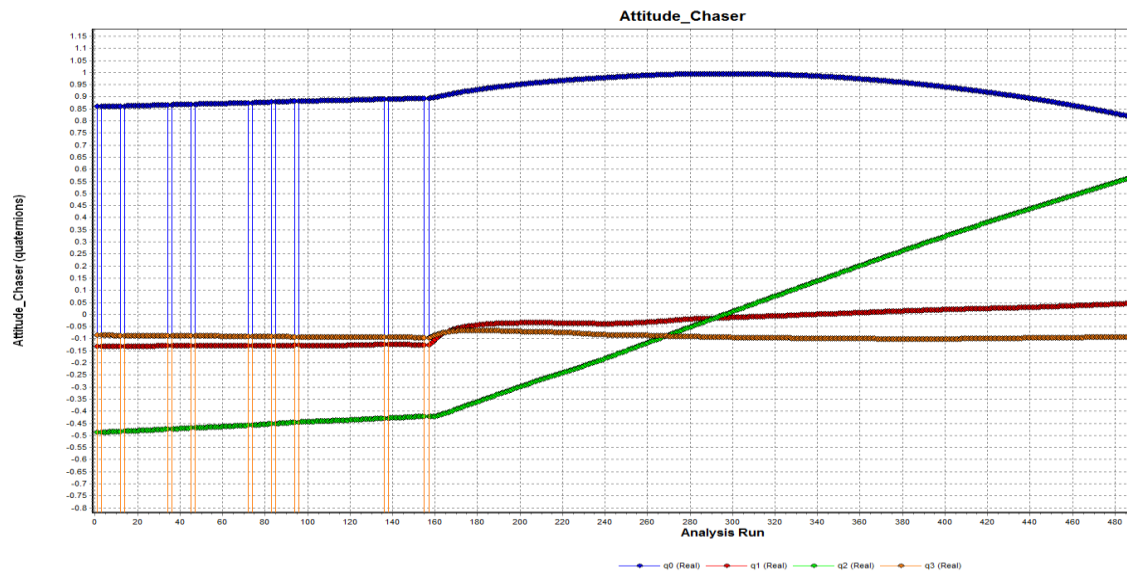
Model execution for getting system responses in various mission scenarios



Data exploration based on system response simulations

Check of requirements according to system performance

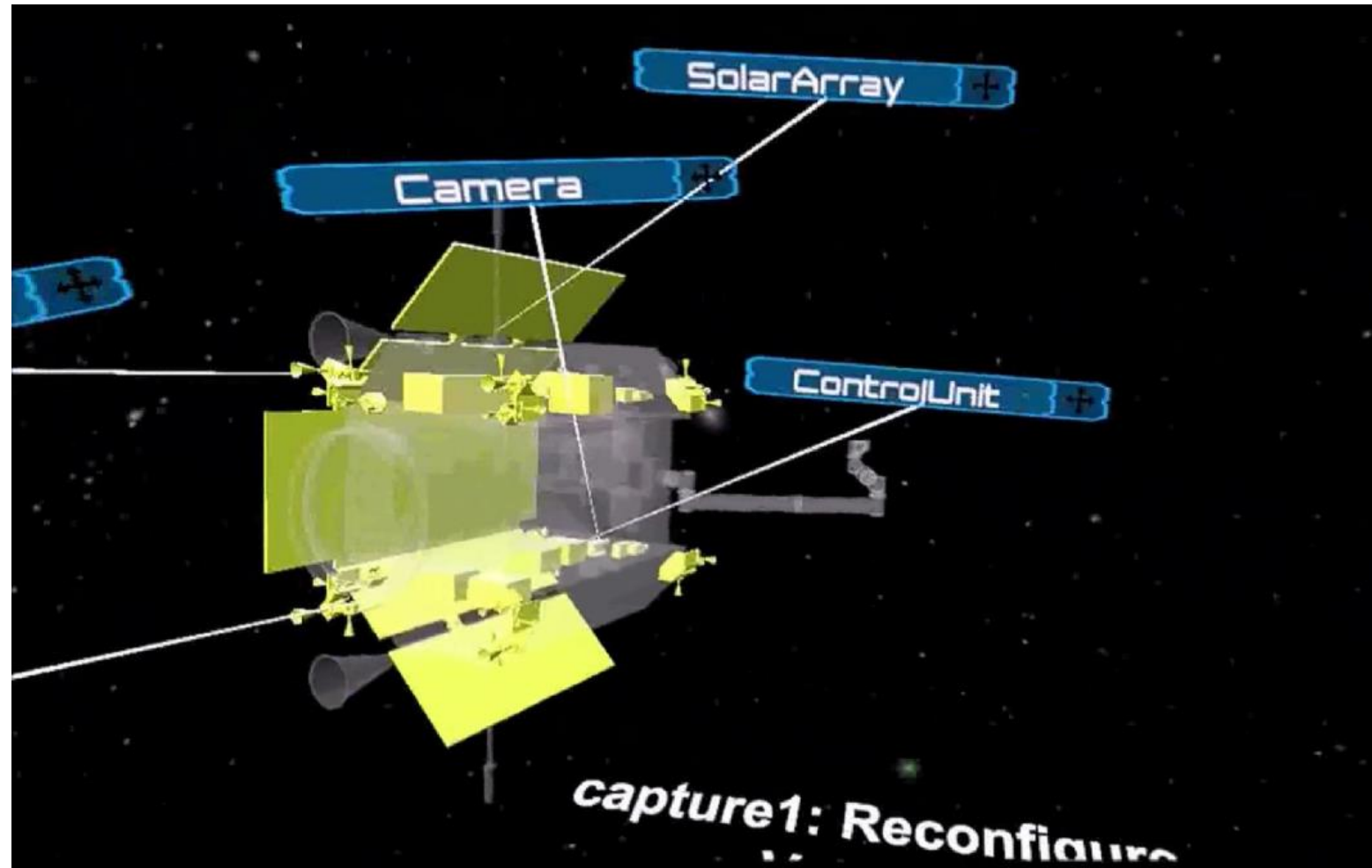
- Analysis of the system responses for different domains in the same mission context.
- Sensitivity analysis of the system w.r.t. environment changes.
- Check if the performance requirements are always fulfilled for different mission scenarios (regression test).
- Control of the margins on the performances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



System synthesis in an integrated VR environment

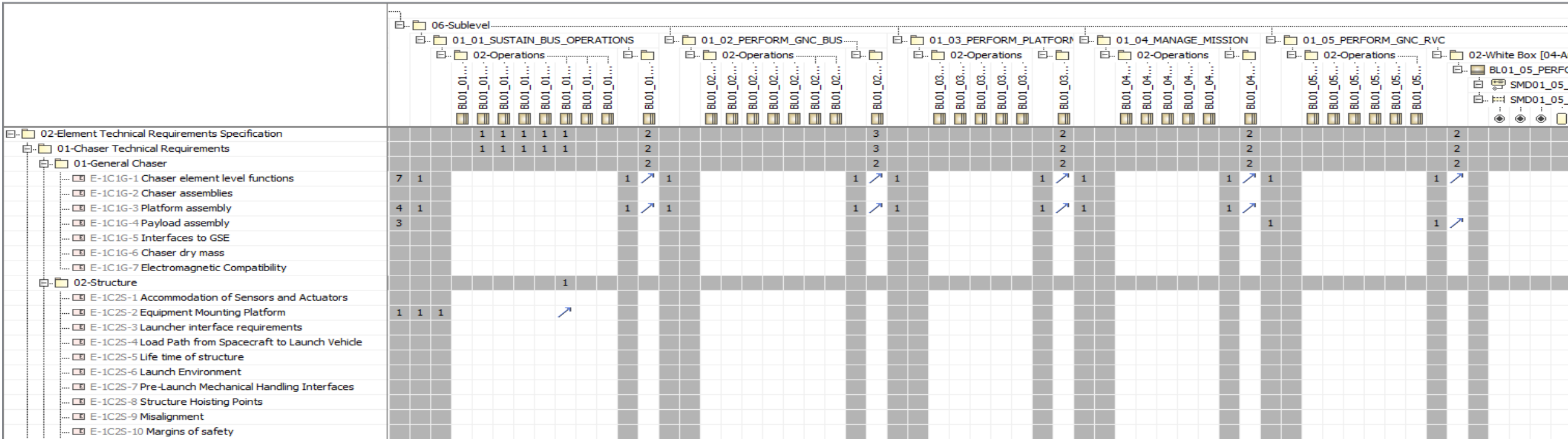
Synthesis of the model data in one digital twin environment

- 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



Transformation of models into requirements

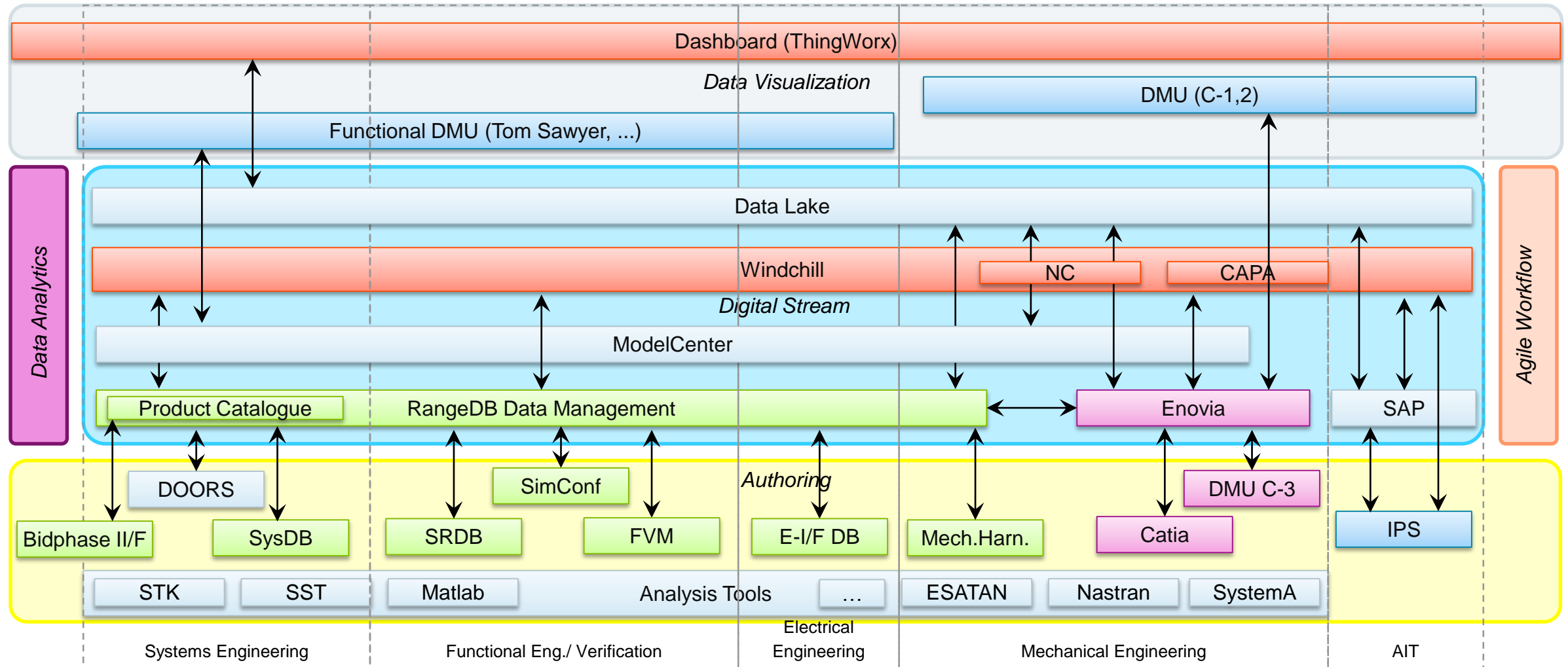
Mapping of requirements to the model architectures with the ‘Satisfied by’ relationship



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 |