



Enabling MBSE with Simulation to perform System Analysis for SOLARIS

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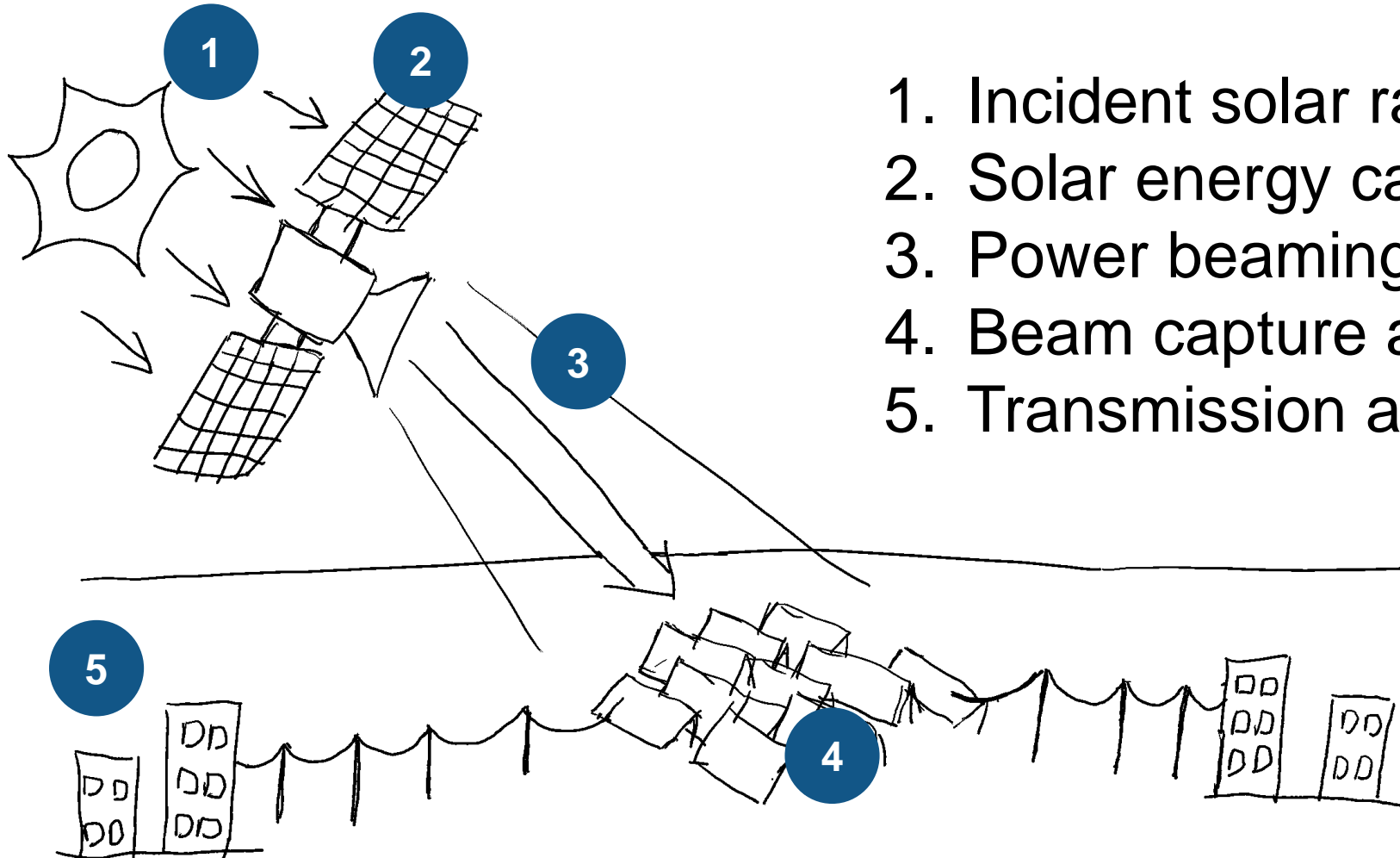


Agenda

- What is SOLARIS?
- Why use MBSE in SOLARIS?
- What are the main challenges/needs?
- Solution
 - Process/methodology
 - Bridge between Capella and System Composer
 - Analysis Workflow
- Outcomes & Concluding Remarks
- Q&A

What is SOLARIS about?

- Space-Based Solar Power involves harvesting sunlight from Earth orbit then beaming it down to the surface where it is needed.

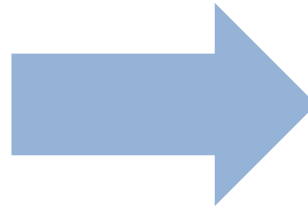


1. Incident solar radiation
2. Solar energy capture and regulation
3. Power beaming
4. Beam capture and conversion
5. Transmission and distribution

Why use MBSE in Solaris?

Architecture design

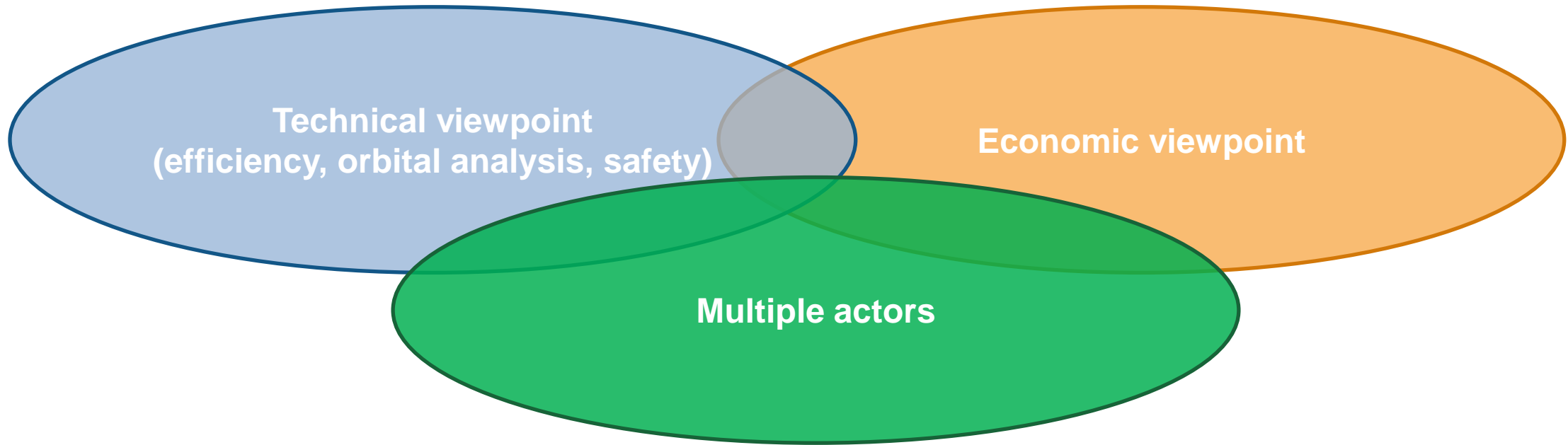
1. Design the architecture with a MBSE method and deliver to ESA a digital model
2. Follow the development of several trade-off with several systems strongly interconnected



Architecture optimization

1. How can we harmonize the different technologies to obtain the best compromise?
2. How can we analyze different kind of data interconnected among each others?

What are the main challenges/needs?

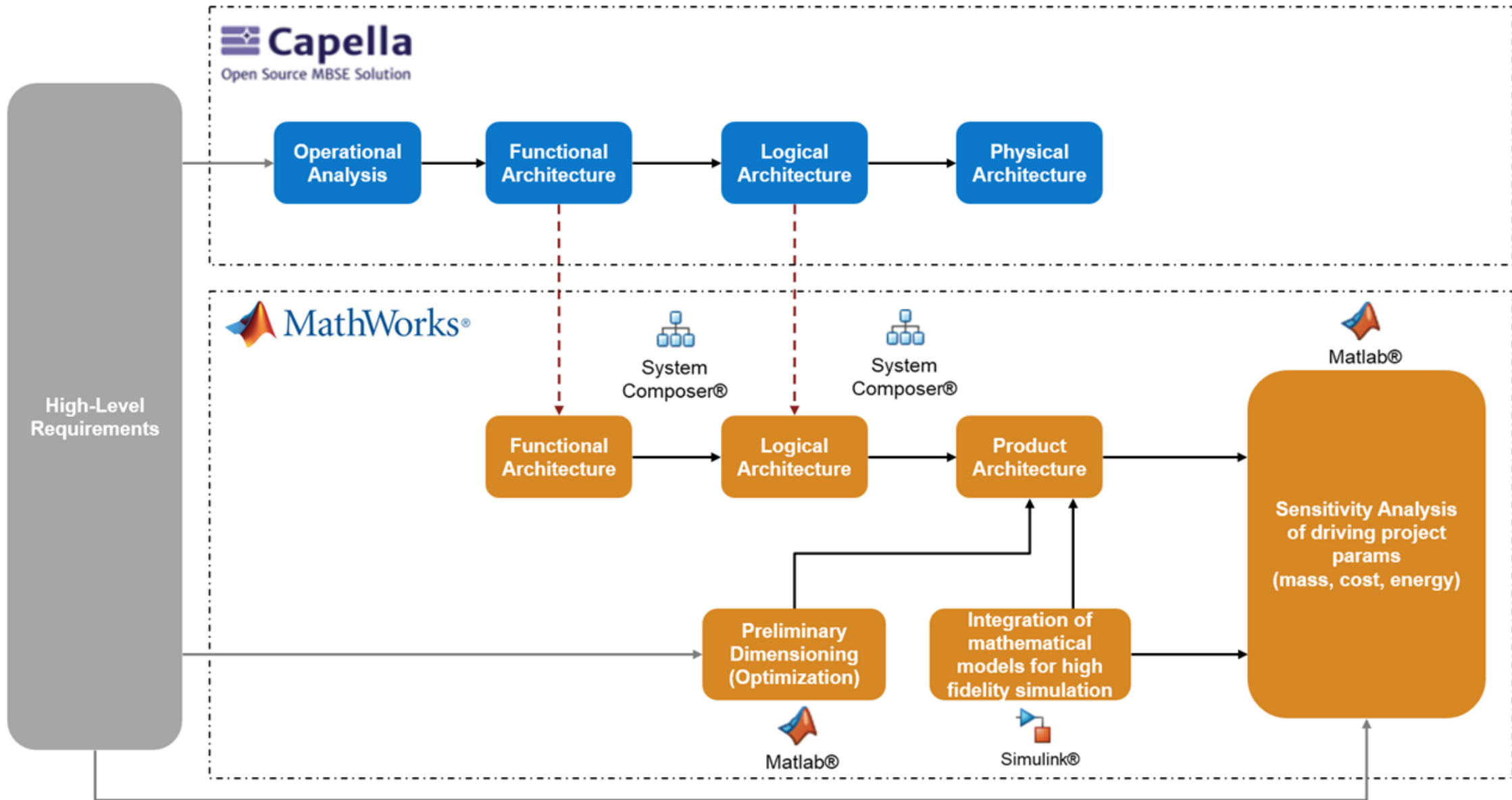


Static point of view (Capella)



Dynamic point of view
(System Composer,
Simulink)

Solution - Process/methodology

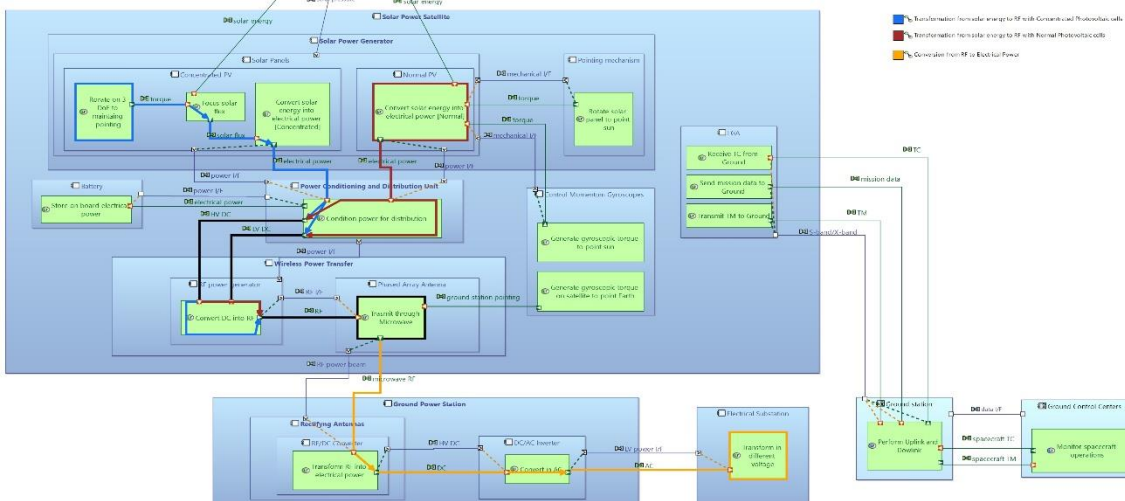


Solution - Bridge between Capella and System Composer

Satellite

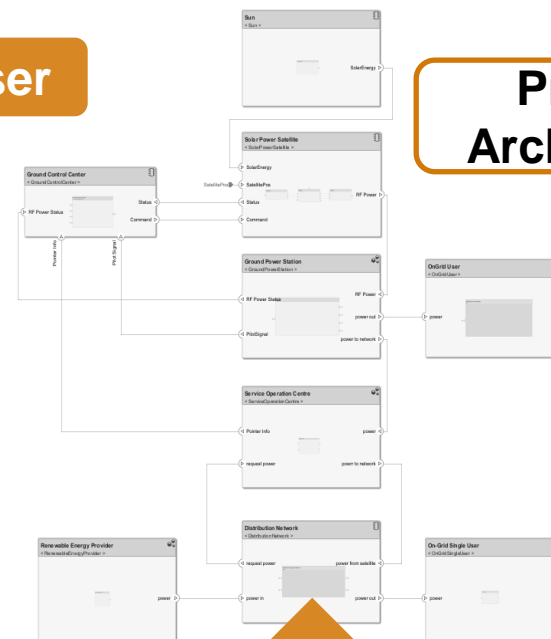


Capella Model

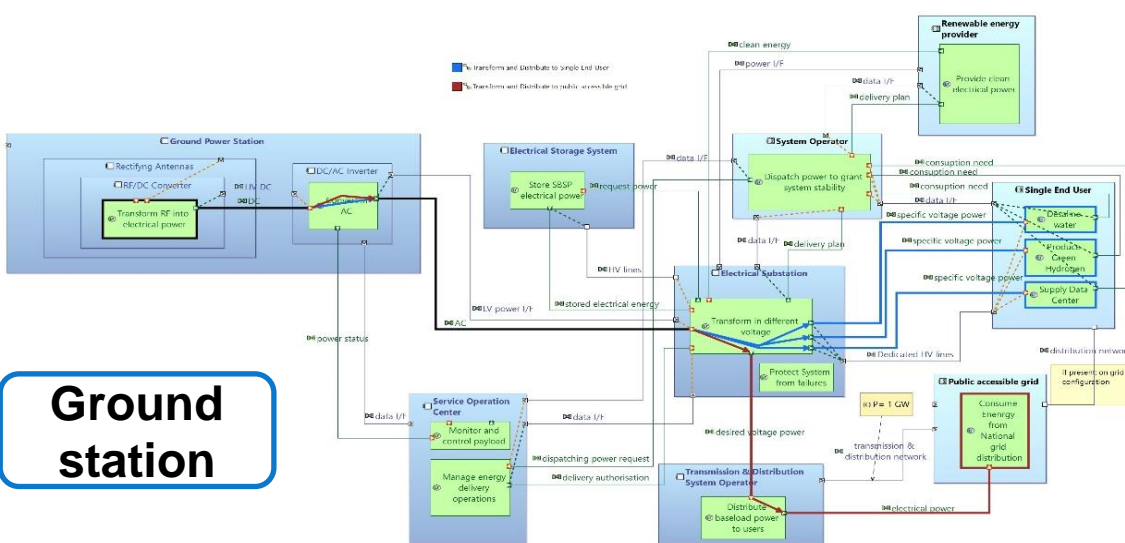


System Composer

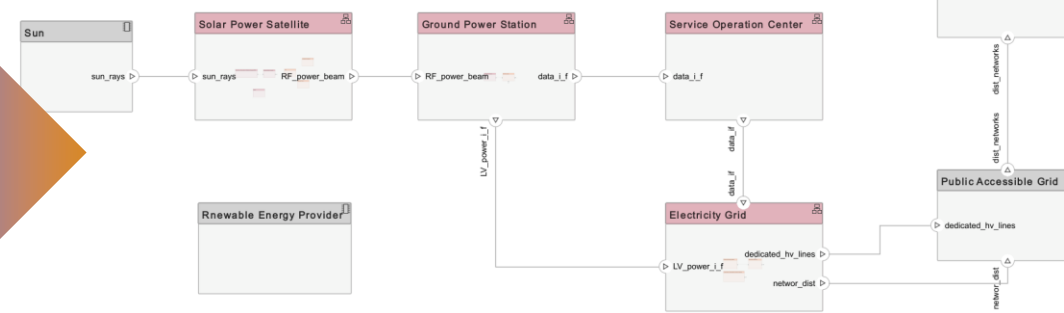
Product Architecture



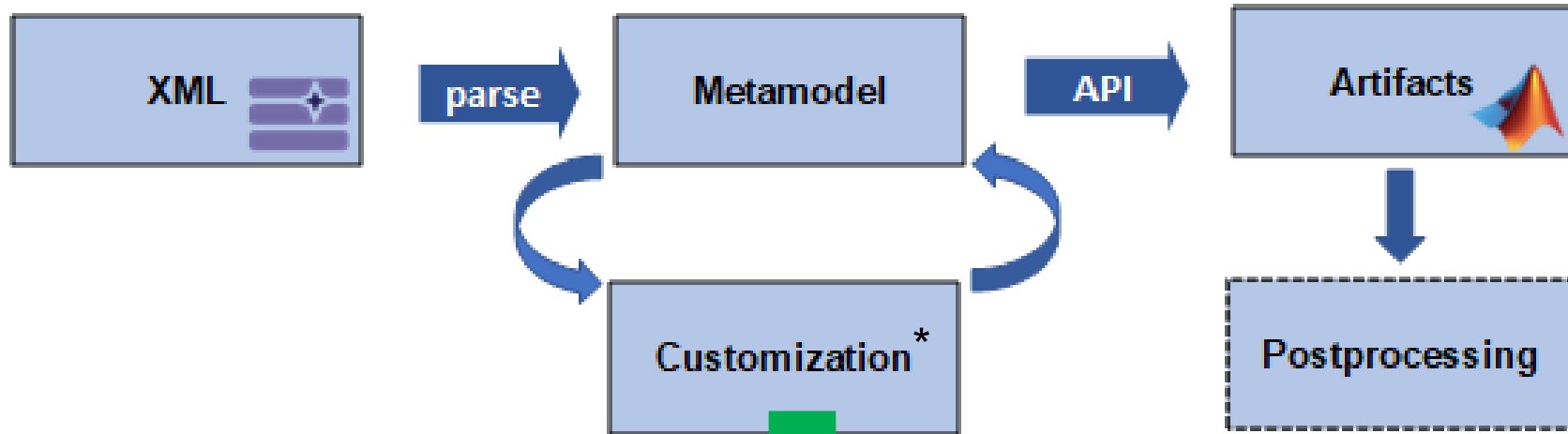
Logical Architecture



Ground station



Solution - Bridge between Capella and System Composer

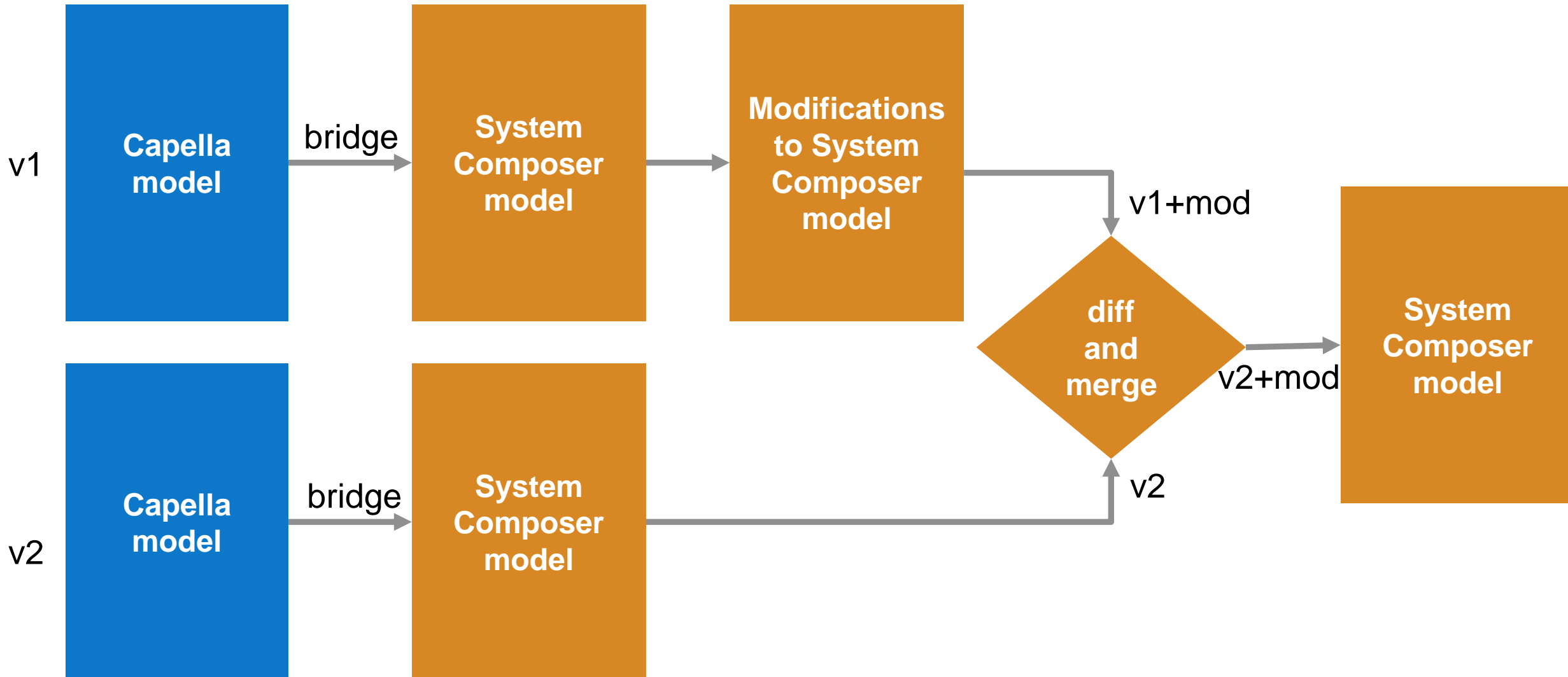


Capella →	→ System Composer
LogicalArchitecture	Architecture model
LogicalComponent	Architecture model
ComponentExchange	Root-level port with composite interface
FunctionalExchange	Connector
ExchangeItem	Interface item
Datatype	Interface item type
Class	Composite interface

* can be customized for other objects and mappings like requirements, profiles, etc.

Solution - Bridge between Capella and System Composer

Digital continuity



Solution - Analysis Workflow

Low Fidelity Analysis

- Objective: Find optimal combination of the Photovoltaic (PV) area, antenna area, and GPS area
- Design Choices
 - (3) Cell technology
 - (3) Ground Station Location
 - (2) Transmission Frequency

SBSP Analysis Framework

Mission Definition | Analysis Set Up | Analysis Result | Analysis Plots

Define Multisimulation Parameters & Settings

Analysis Type: Low Fidelity

Generate Sim Report: No

Optimization Weights List

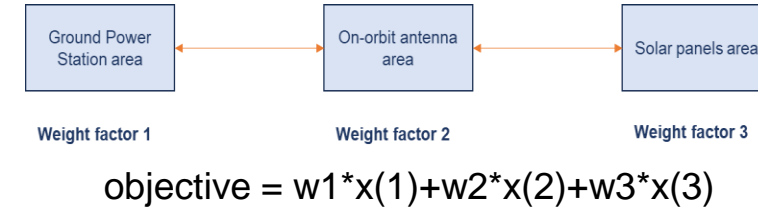
Parameter Name	Parameter Value
WGroundStation	1
WAntenna	30
WSolarPanel	30

Target Power [GW]: 1

Define Fixed Parameter Values

Parameter Name	Parameter Selection	Parameter Value
CellTechnology	Perovskite	[29% 0.3Kg/m ²]
GroundPowerStationLocation	Spain	[40.2085°Lat -3.7130°Long]
TransmissionFrequency	F_5_8	[5.8GHz]

Run



Mission Definition | Analysis Set Up | Analysis Result | Analysis Plots

Running Simulation: 6/6

Starting Analysis for SBPS with the following parameters:

Scenario Type: Scenario #2 - Full-scale space-based mission

Analysis Type: Low Fidelity

Variable parameters:

- GroundPowerStationLocation
- TransmissionFrequency

Fixed Parameters parameters:

- CellTechnology

#	Ground Power Station Lat (°)	Transmission Frequency (GHz)	Cell Efficiency (%)	Ground Power Station Area (Km ²)	Antenna Area (Km ²)	Solar Panel Area (Km ²)	Total Efficiency (%)
1	40.2085	2.45	29	53.2922	0.87479	5.926	1.4
2	40.2085	5.8	29	25.494	0.39651	6.2034	1.84
3	51.1657	2.45	29	72.2886	0.89906	5.9367	1.38
4	51.1657	5.8	29	29.7018	0.45058	6.1999	1.85
5	60.1282	2.45	29	103.9448	0.92116	5.9467	1.36
6	60.1282	5.8	29	41.6778	0.4762	6.2001	1.85

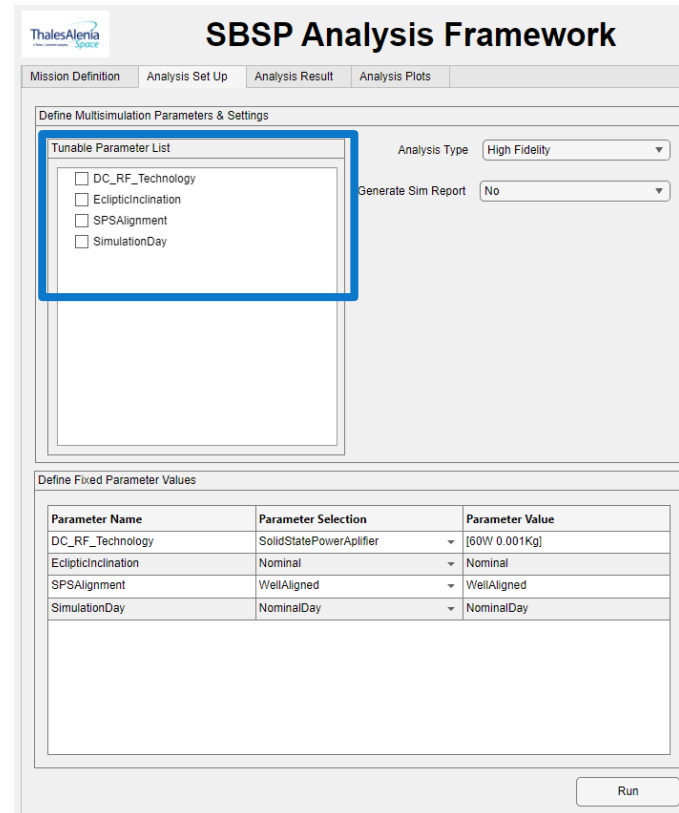
Export To Architecture

3 x 3 x 2 = 18 unique variant combinations

Solution - Analysis Workflow

High Fidelity Analysis

- Objective:
 - High-fidelity power simulations in various mission scenarios
 - Preliminary mass and cost estimation
- Design Choices
 - (3) DF-RF Technology
 - (2) Simulation Day
 - (2) Ecliptic inclination
 - (2) SPS Alignment



Ecliptic Inclination [-]	Average Transmission Power (MW)	Total Mass (T) & Total Launch(-)	Mission Cost (B\$) & LCOE (\$/MWh)	EROEI (-) & Energy Paybacktime (days)
Nominal	<ul style="list-style-type: none"> • @PVA=2064 • @PMainBus=1979 • @On-board Antenna=1577 • @GPS=1051 • @Grid=993 	<ul style="list-style-type: none"> • tot_mass=6591 • tot_launch=106 	<ul style="list-style-type: none"> • miss_cost=14 • LCOE=191 	<ul style="list-style-type: none"> • EROEI=42 • EPBT=219
Nominal	<ul style="list-style-type: none"> • @PVA=1883 • @PMainBus=1805 • @On-board Antenna=1439 • @GPS=959 • @Grid=993 	<ul style="list-style-type: none"> • tot_mass=6591 • tot_launch=106 	<ul style="list-style-type: none"> • miss_cost=14 • LCOE=191 	<ul style="list-style-type: none"> • EROEI=42 • EPBT=219

3 x 2 x 2 x 2 = 24 unique variant combinations

Solution - Analysis Workflow

Architecture Metadata

Platform Sim Environment

Architecture	Info	VALUE
NAME		
▼ Main		
Name	PlatformArch	
Stereotype	Add...	
▼ LowFidelityAnalysisResult	Select	
GroundPowerStationArea	25.494 Km ²	
AntennaArea	0.39651 Km ²	
SolarPanelArea	6.2034 Km ²	
TotalEfficiency	11.84 GHz	
eta_pv	0.23229	
eta_DCRF	0.83	
eta_airy	0.83202	
eta_RFDC	0.83413	
CellEff	29 %	
CellDensity	0.3 Kg/m ²	
▼ TunableParameters	Select	
TransmissionFrequency	F_2_45	
CellTechnology	Perovskite	
DC_RF_Technology	Klystron	
GroundPowerStationLocation	Spain	
OrbitType	GEO	
CommsStatus	On	
WeatherCondition	Sun	
SPSAlignment	WellAligned	
SimulationDay	NominalDay	
EclipticInclination	Nominal	

Platform Architecture

SBSP Analysis Framework

Running Simulation: 6/6

Starting Analysis for SBSP with the following parameters:
 Scenario Type: Scenario #2 - Full-scale space-based mission
 Analysis Type: Low Fidelity
 Variable parameters:
 - CellTechnology
 - TransmissionFrequency
 Fixed Parameters parameters:
 - GroundPowerStationLocation

Update Architecture with low fidelity analysis Result

Do you want to update the architecture parameter with the following result of the low fidelity analysis:

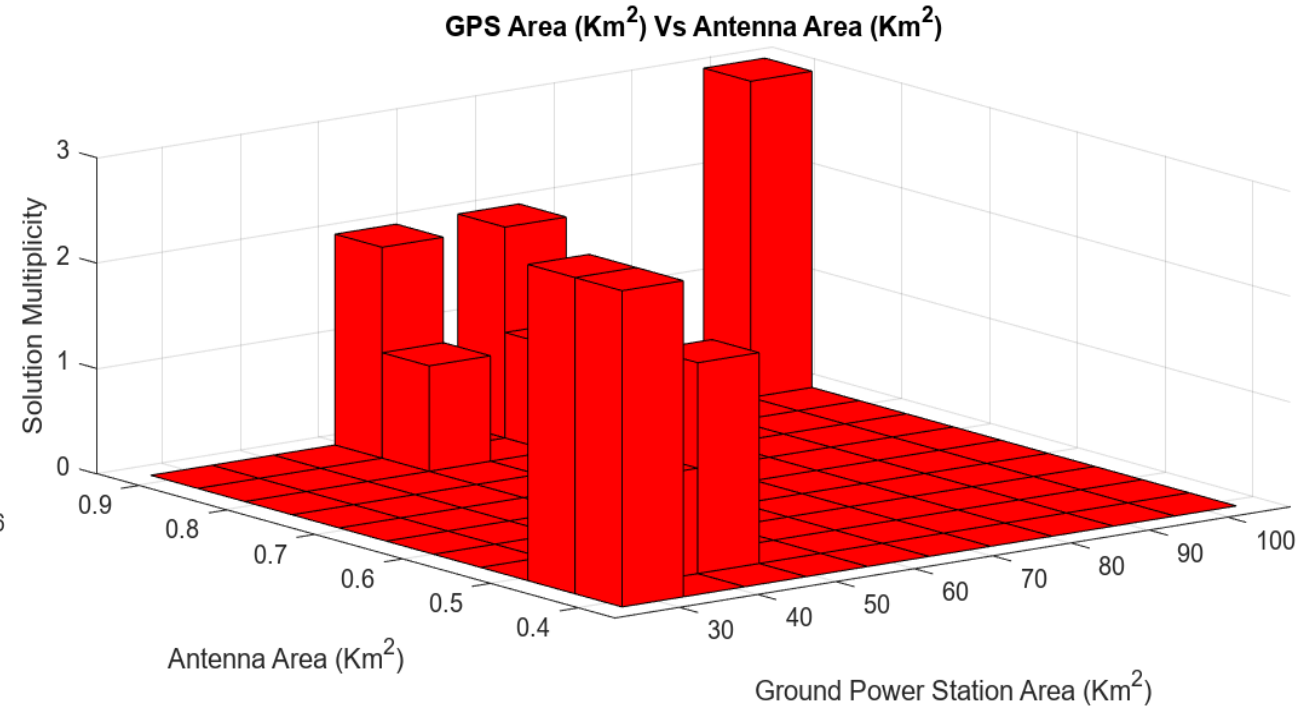
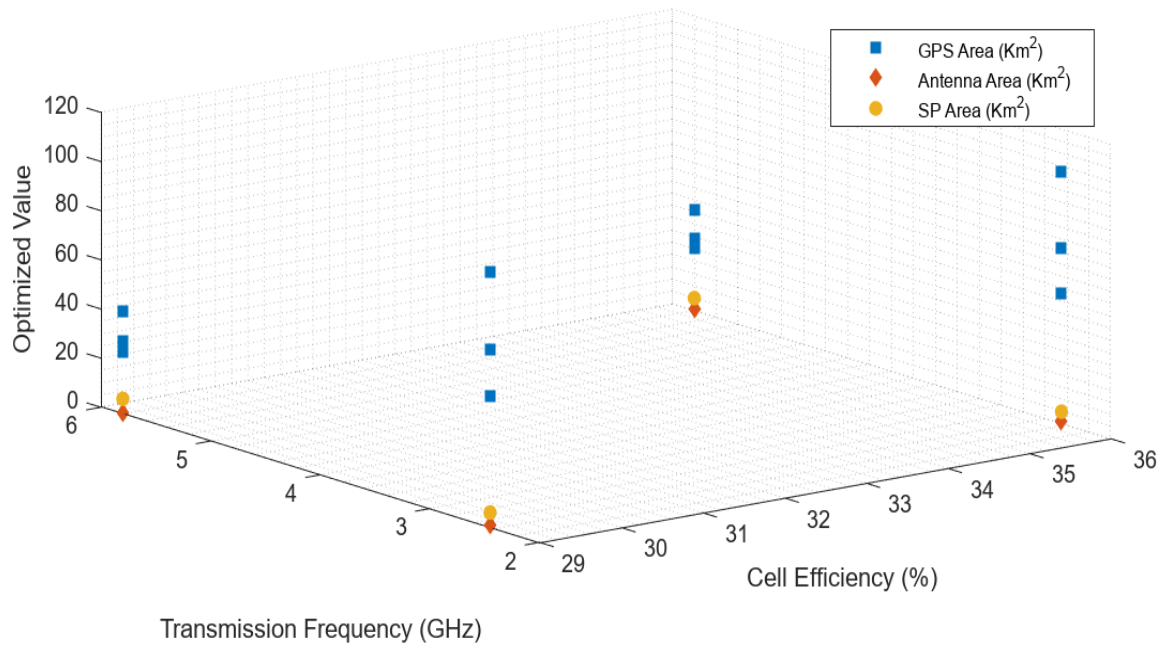
- Ground Power Station Area (Km²) = 28.935
- Antenna Area (Km²) = 0.4877
- Solar Panel Area (Km²) = 6.2542
- Total Efficiency (%) = 11.75

#	G	P	S	L	Total Efficiency (%)		
1	4				15.05		
2	4				12.26		
3	40.2085	2.45	29	65.384	0.99446	5.9926	12.26
4	40.2085	5.8	36	30.4559	0.45105	5.0616	14.52
5	40.2085	5.8	29	28.935	0.4877	6.2542	11.75
6	40.2085	5.8	29	28.9351	0.4877	6.2542	11.75

Export To Architecture

Mission Analysis

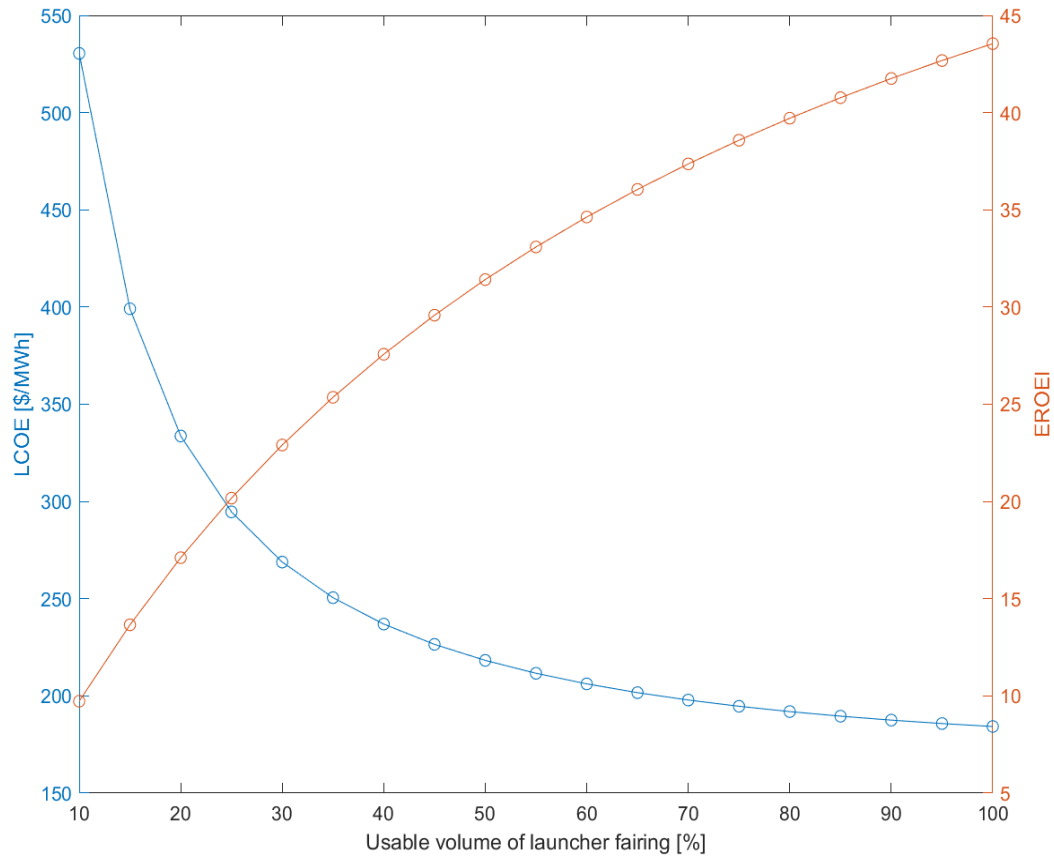
Solution – Low-Fidelity analysis results



- Scatter plot of results obtained with different input parameters combination

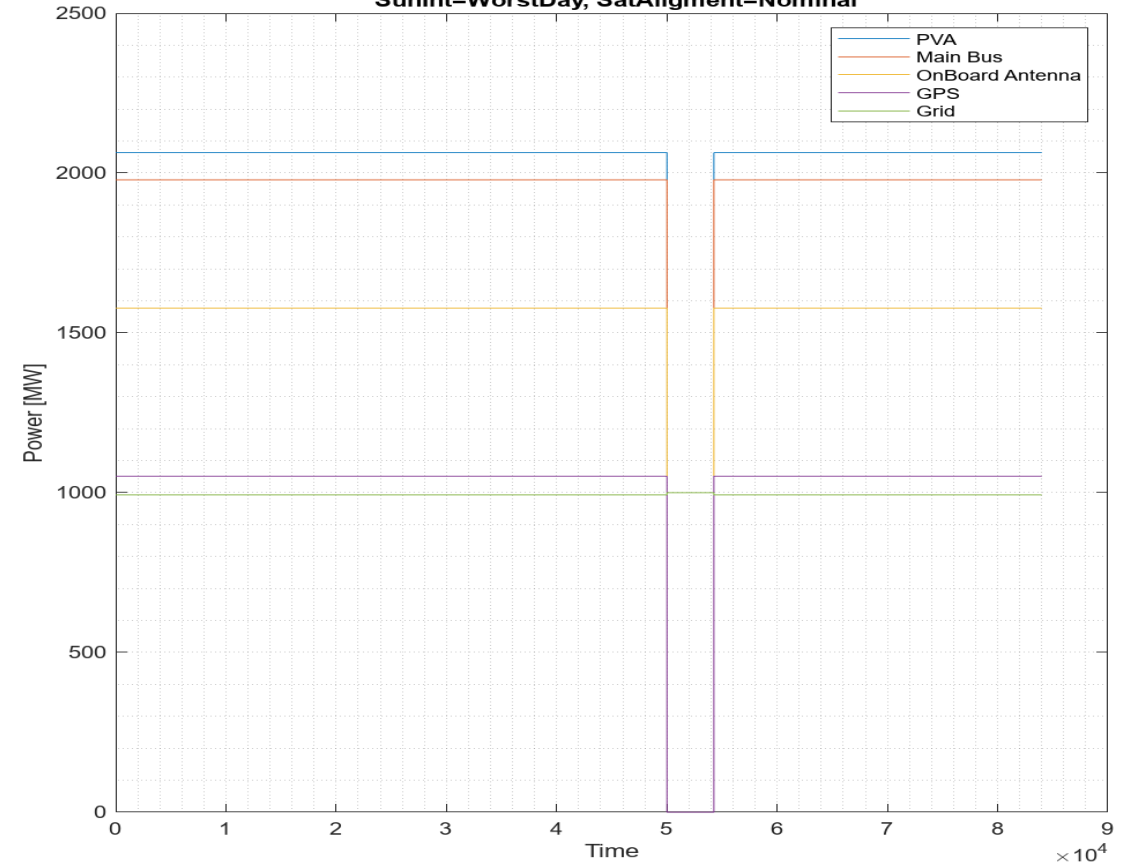
- Multiplicity of the 3 main areas combination solutions obtained during a simulation

Solution – High-Fidelity analysis results



- Sensitivity analysis on LCOE and EROEI wrt launcher fairing fill factor

Sim#1: DCRFTech=SolidStatePowerAplifier,
SigAlignment=WellAligned,
SunInt=WorstDay, SatAlignment=Nominal



- Power simulation of the SBSP architecture during a worst-case eclipse day

Outcomes

- **Comprehensive Understanding**, systematic analysis of the mission
- **Simulation of Complex Scenarios**, different solar conditions, orbit variations, etc.
- **Data-Driven Insights** using digital models
- **Efficiency Improvements**, optimize system components
- **Risk Mitigation**, identify challenges early
- **Iterative Design**, refine and improve the mission design over time
- **Cost and Resource Savings**, reduce the need for physical prototypes
- **Communication and Collaboration**, models facilitate effective communication

Concluding Remarks

- **Expandability:**
This framework (Bridge and Analysis) is designed to be expandable to the next phases of this study and other missions/projects.

- **Cross-tool operability:**
This framework demonstrates operability between Capella and System Composer and other MBSE tools .



Q&A

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