Capella Days 2024

Where the Capella Community Meets

November 19-21

Online & Free

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Enabling MBSE with Simulation to perform System Analysis for SOLARIS

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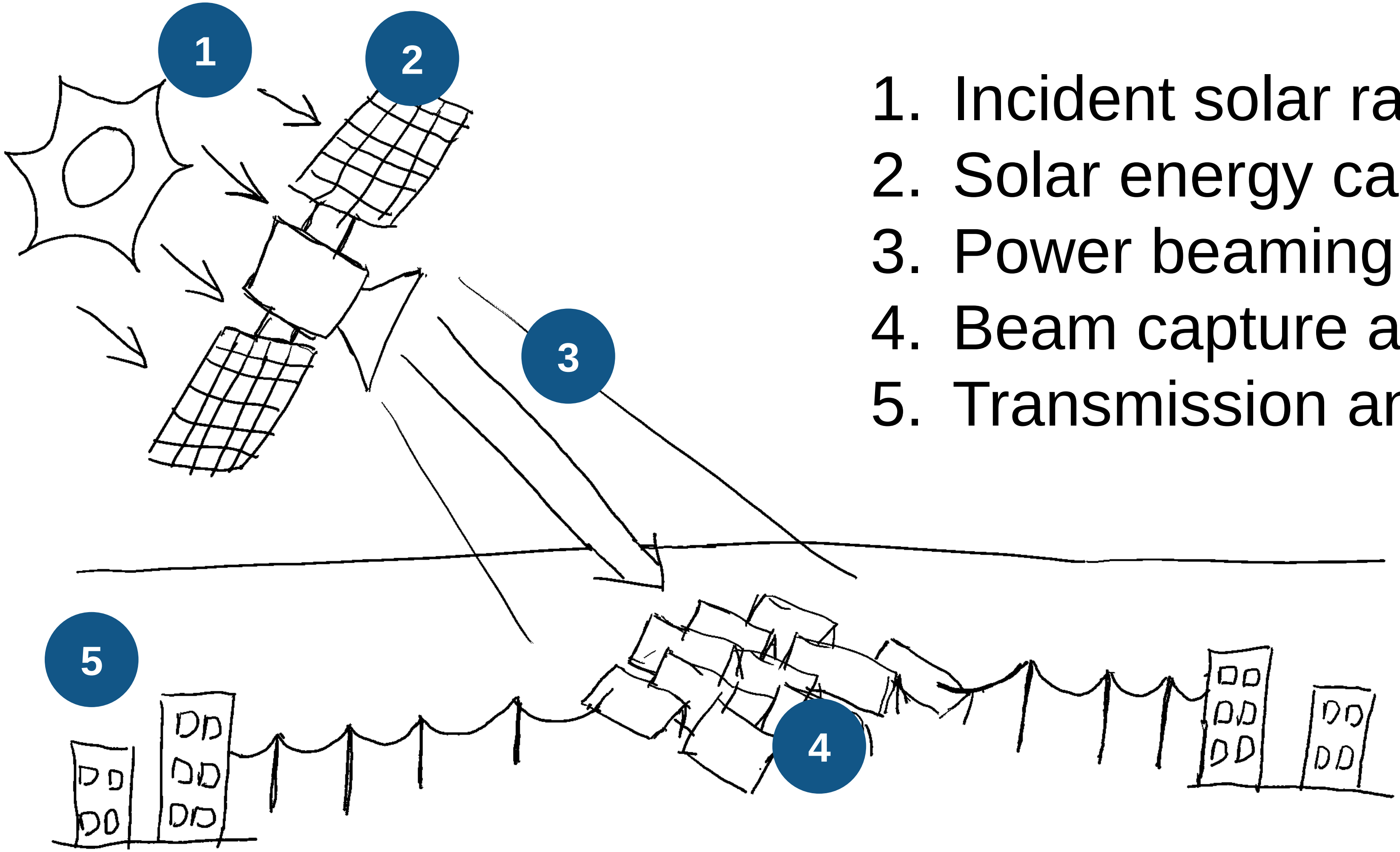
Agenda

- 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?

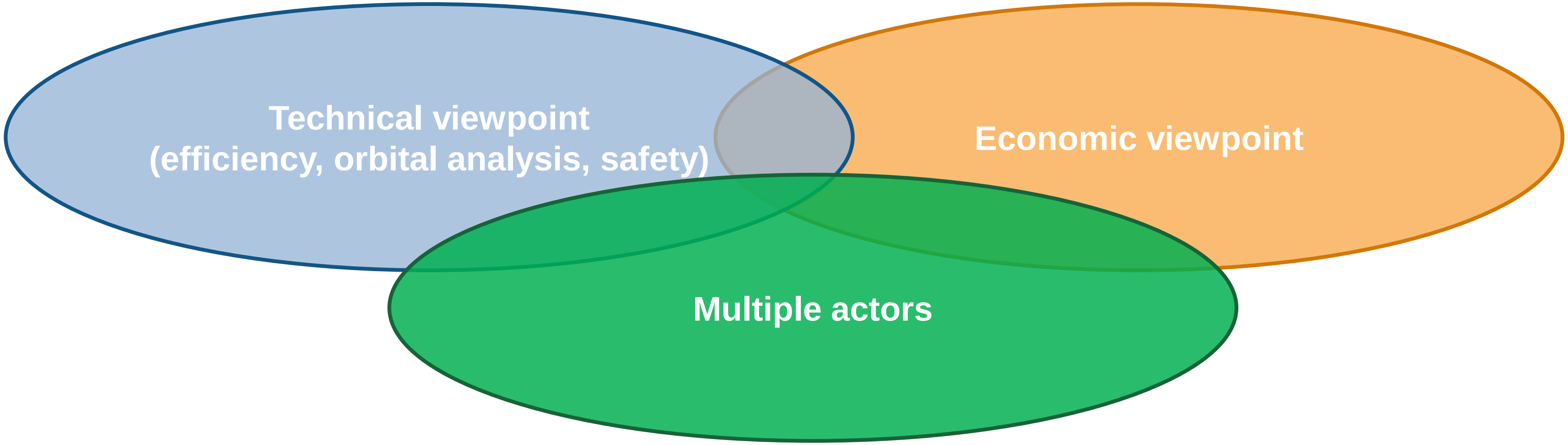
Architecture design

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?

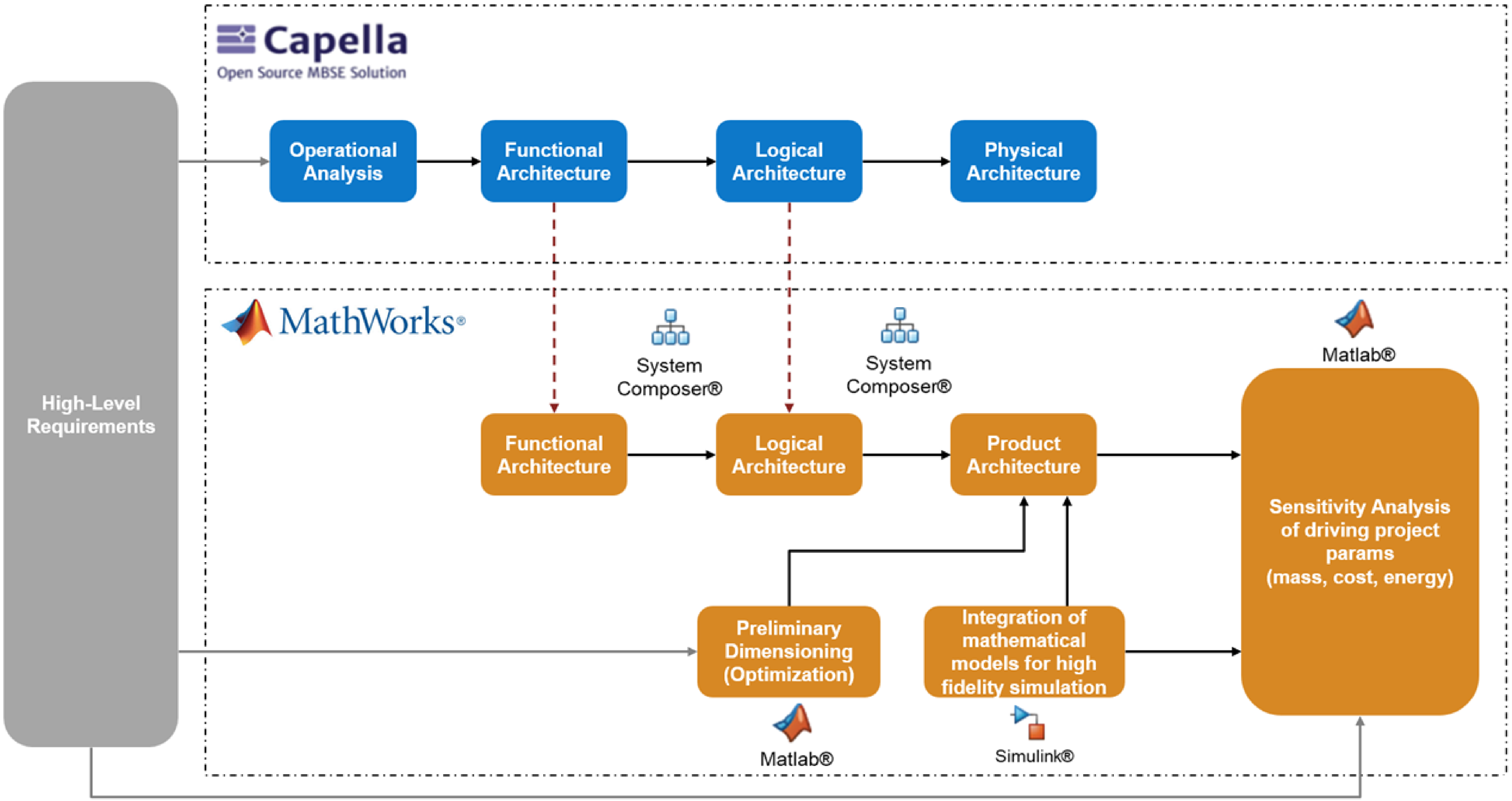
What are the main challenges/needs?



Static point of view (Capella)

Dynamic point of view (System Composer, Simulink)

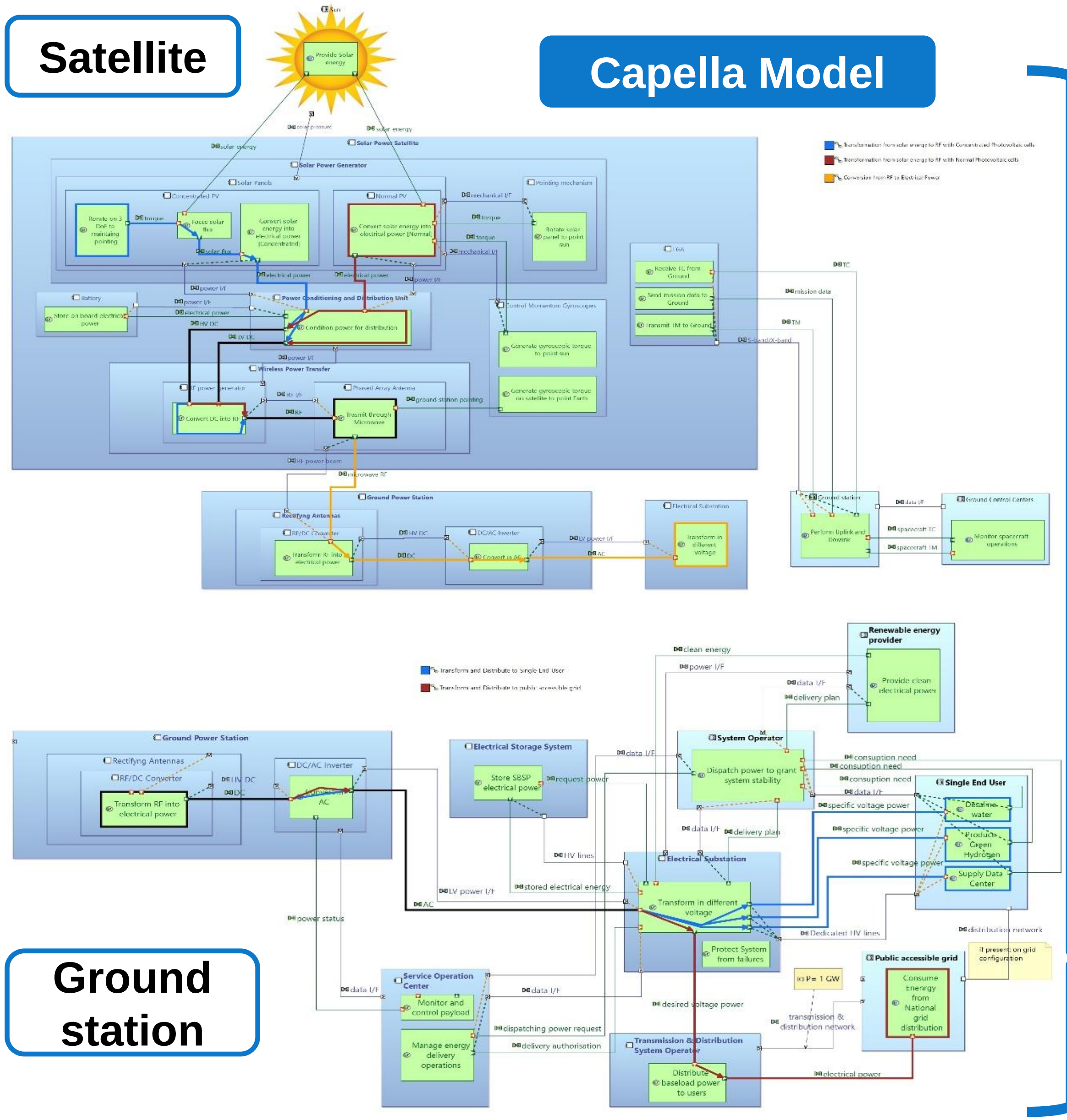
Solution - Process/methodology



Solution - Bridge between Capella and System Composer

Satellite

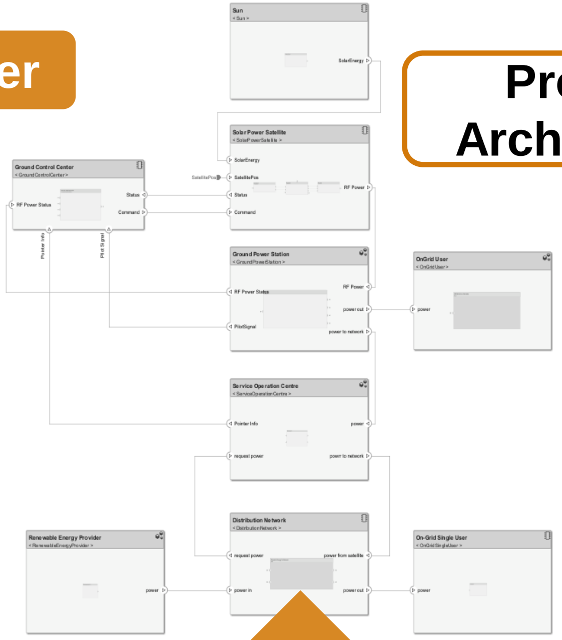
Capella Model



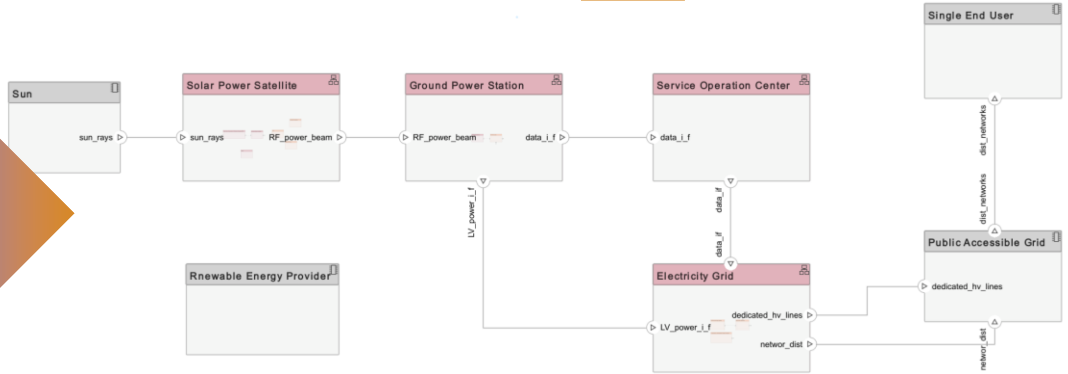
Ground station

System Composer

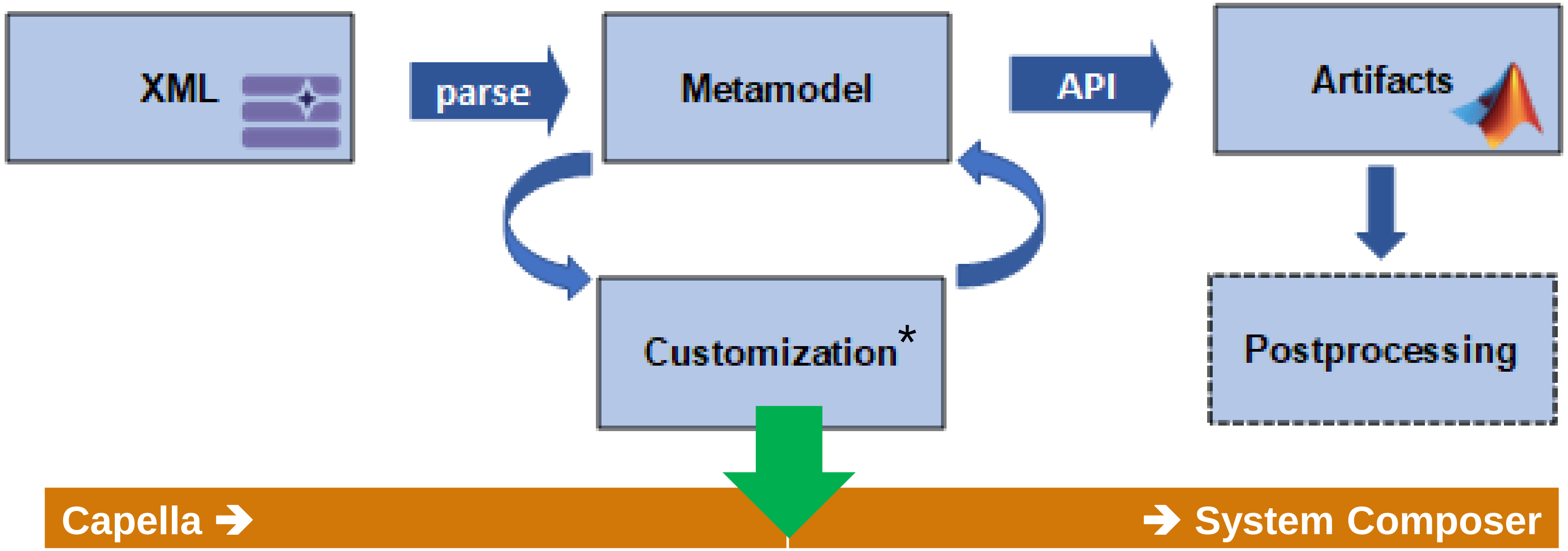
Product Architecture



Logical Architecture



Solution - Bridge between Capella and System Composer



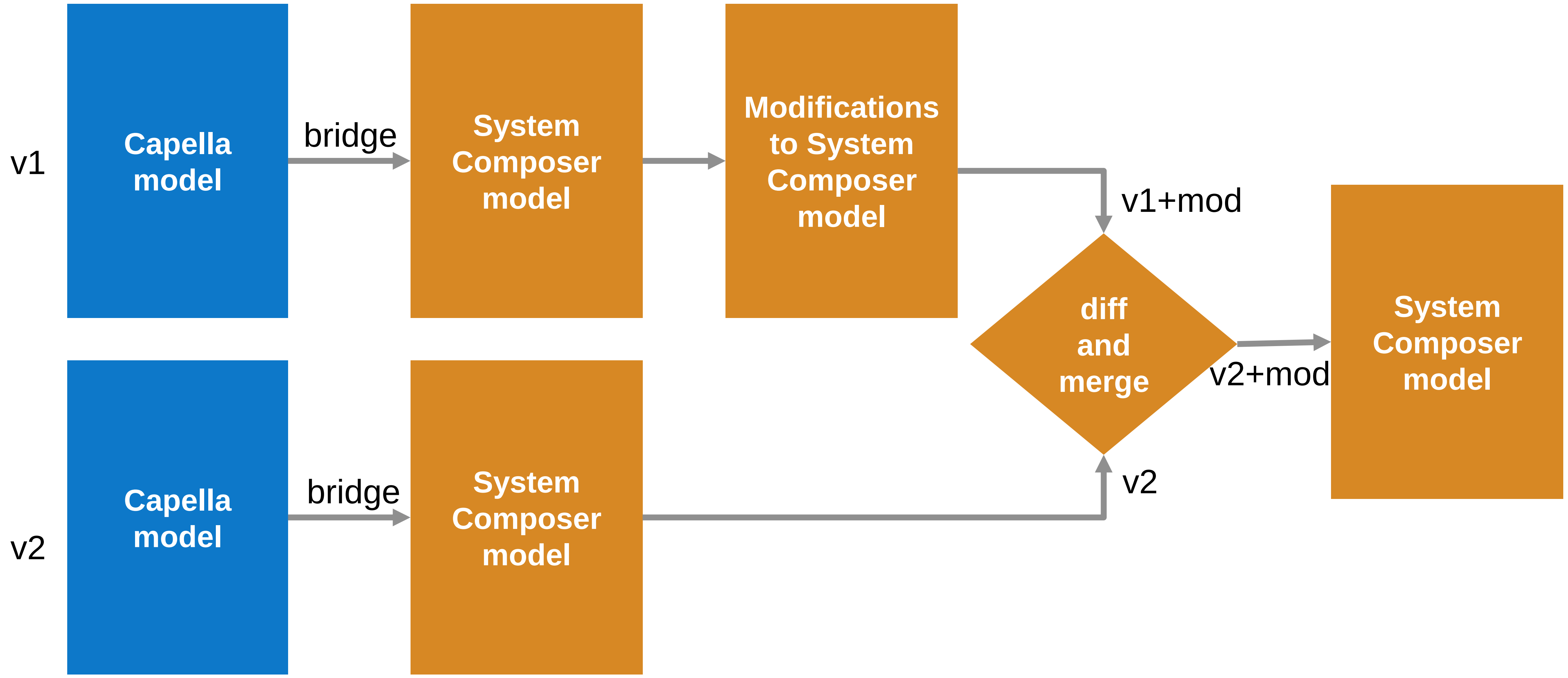
Capella →	→ System Composer
LogicalArchitecture	Architecture model
LogicalComponent	Architecture model
ComponentExchange	Root-level port with composite interface
FunctionalExchange	Connector
ExchangeItem	Interface item
Datatype	Interface item type
Class	Composite interface

Full Article: Creating a Bridge Between Capella and System Composer

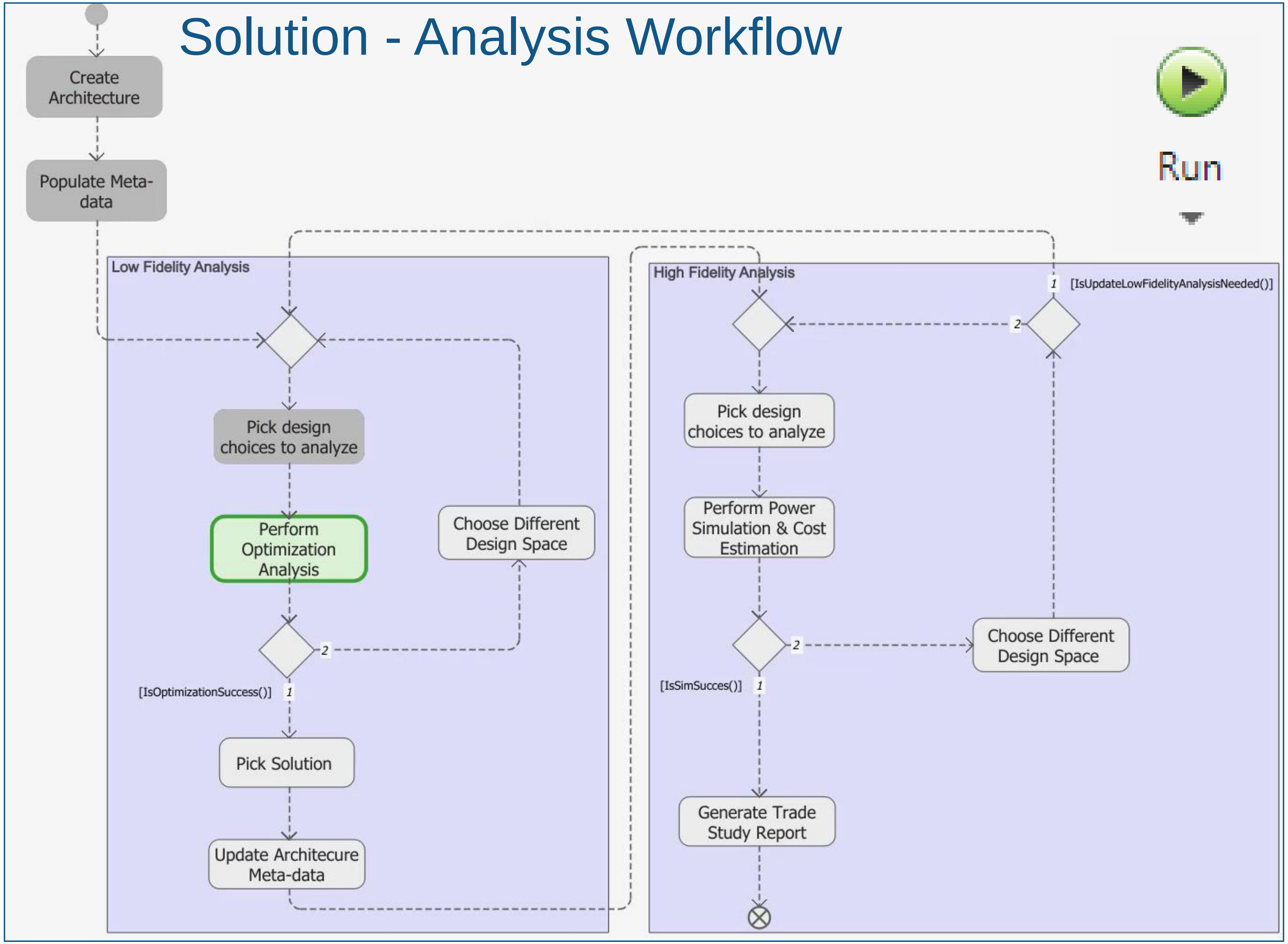
* can be customized for other objects and mappings like requirements, profiles, etc.

Solution - Bridge between Capella and System Composer

Digital continuity



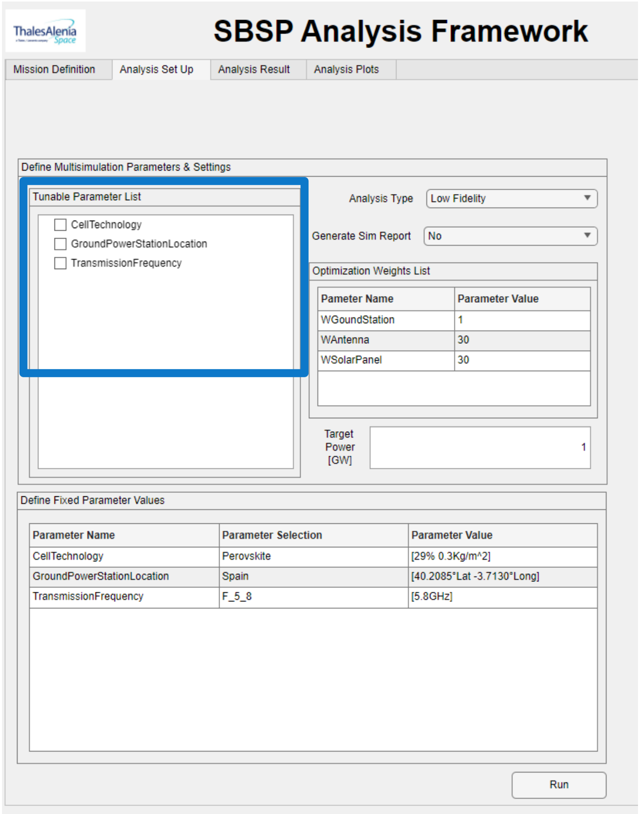
Solution - Analysis Workflow

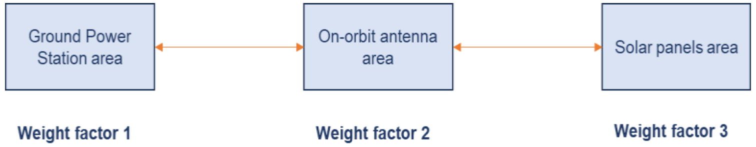


Solution - Analysis Workflow

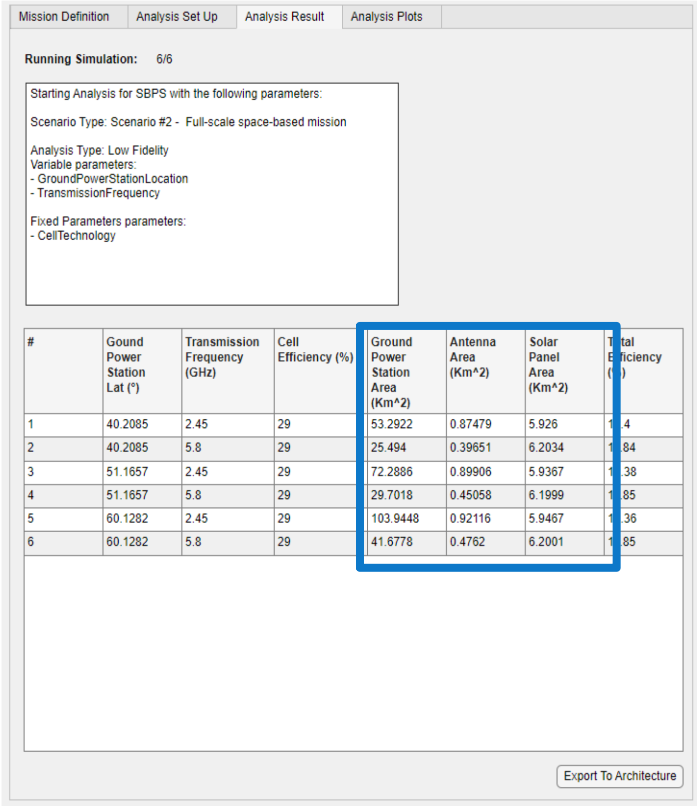
Low Fidelity Analysis

- 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





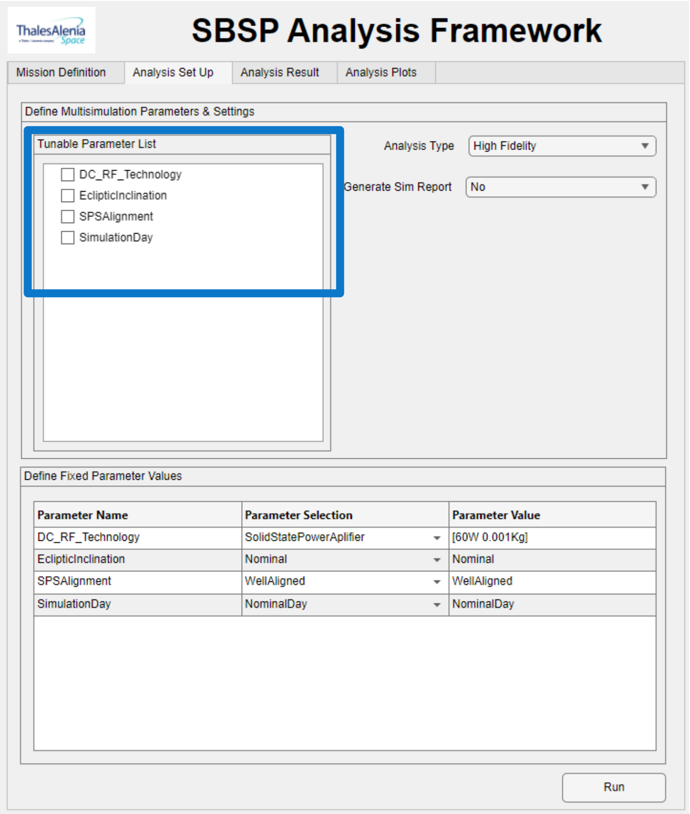
objective = w1*x(1)+w2*x(2)+w3*x(3)



#	Gound 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[illegible].4
2	40.2085	5.8	29	25.494	0.39651	6.2034	1[illegible].84
3	51.1657	2.45	29	72.2886	0.89906	5.9367	1[illegible].38
4	51.1657	5.8	29	29.7018	0.45058	6.1999	1[illegible].85
5	60.1282	2.45	29	103.9448	0.92116	5.9467	1[illegible].36
6	60.1282	5.8	29	41.6778	0.4762	6.2001	1[illegible].85

3 x 3 x 2 = 18 unique variant combinations

Solution - Analysis Workflow



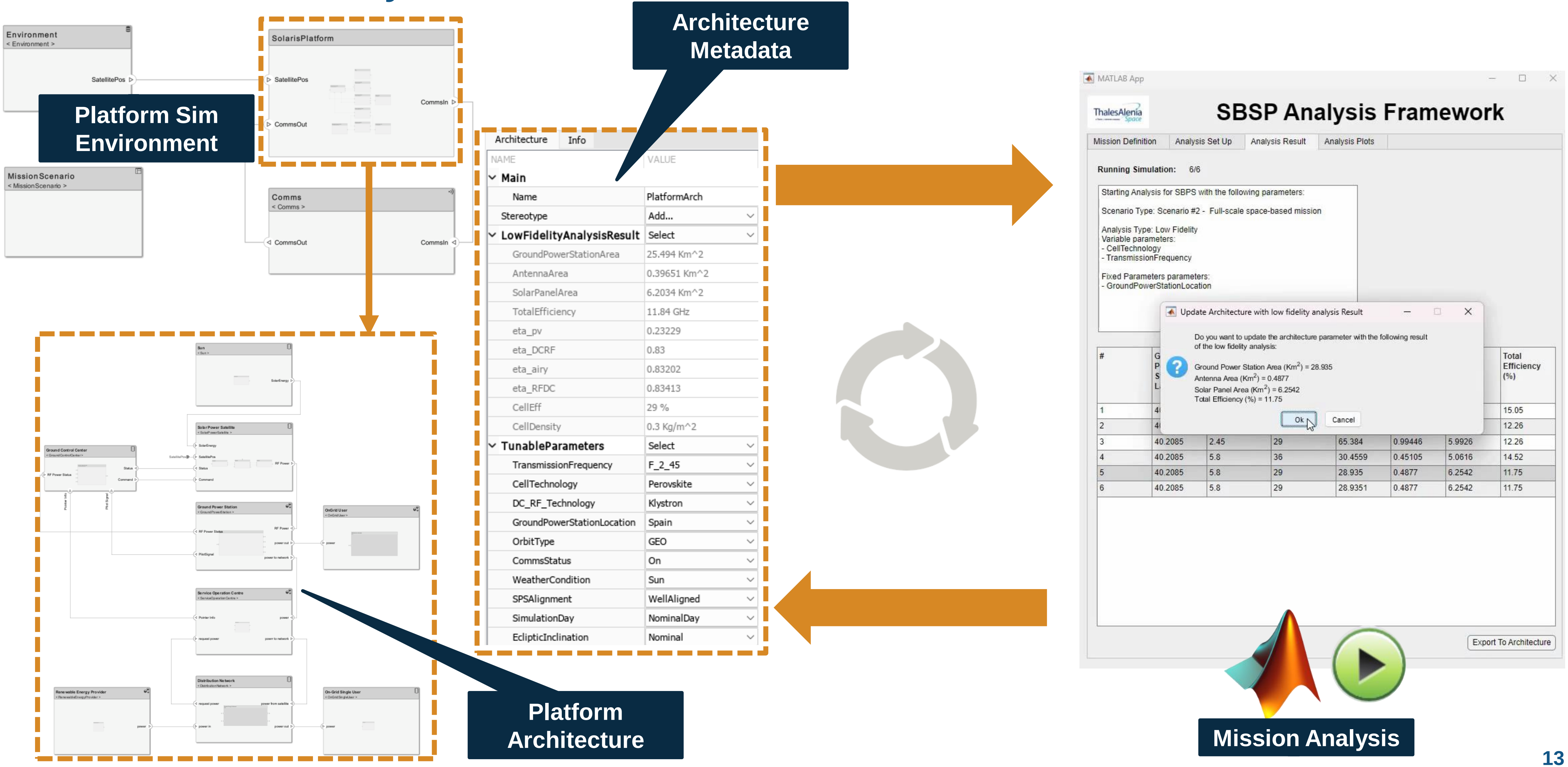
High Fidelity Analysis

- 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

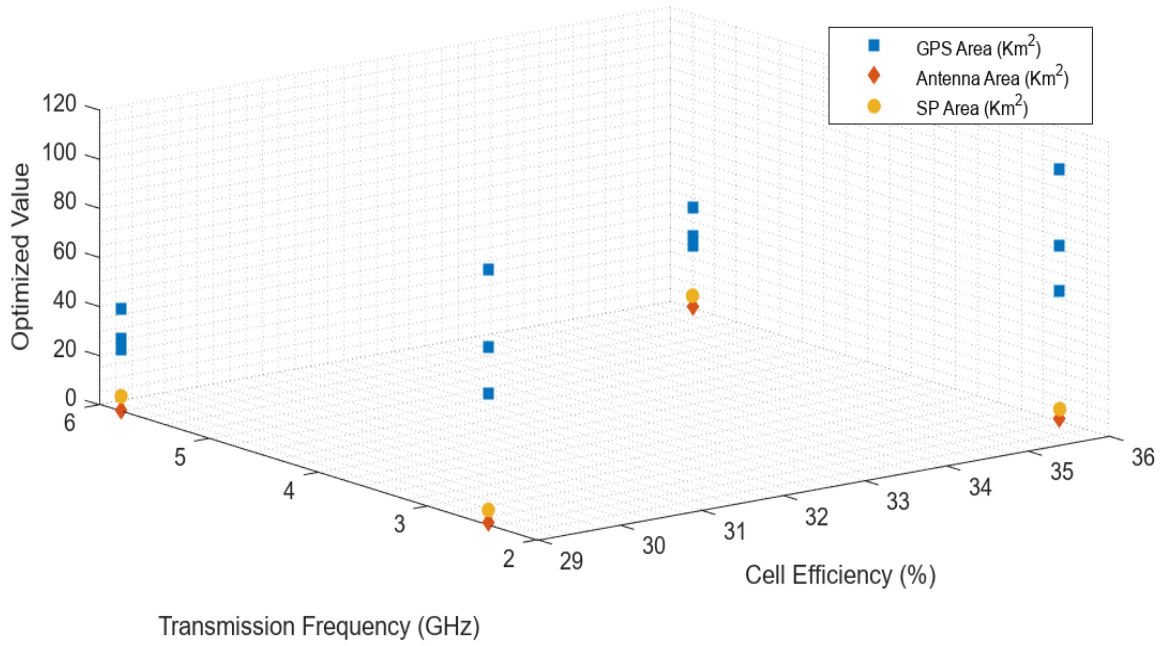
Ecliptic Inclination [-]	Average Transmission Power (MW)	Total Mass (T) & Total Launch(-)	Misson Cost (B$) & LCOE ($/MWh)	EROEI (-) & Energy Paybacktime (days)
Nominal	• @PVA=2064 • @PMainBus=1979 • @On-board Antenna=1577 • @GPS=1051 • @Grid=993	• tot_mass=6591 • tot_launch=106	• miss_cost=14 • LCOE=191	• EROEI=42 • EPBT=219
Nominal	• @PVA=1883 • @PMainBus=1805 • @On-board Antenna=1439 • @GPS=959 • @Grid=993	• tot_mass=6591 • tot_launch=106	• miss_cost=14 • LCOE=191	• EROEI=42 • EPBT=219

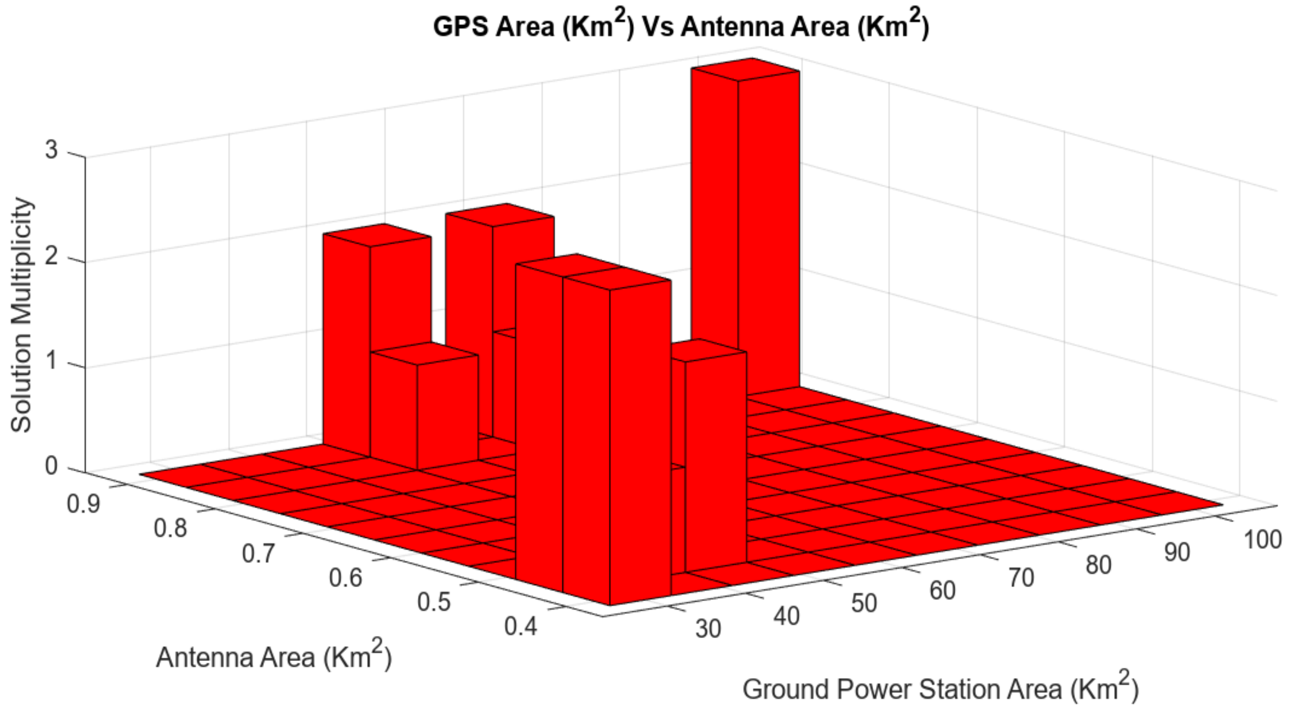
3 x 2 x 2 x 2 = 24 unique variant combinations

Solution - Analysis Workflow



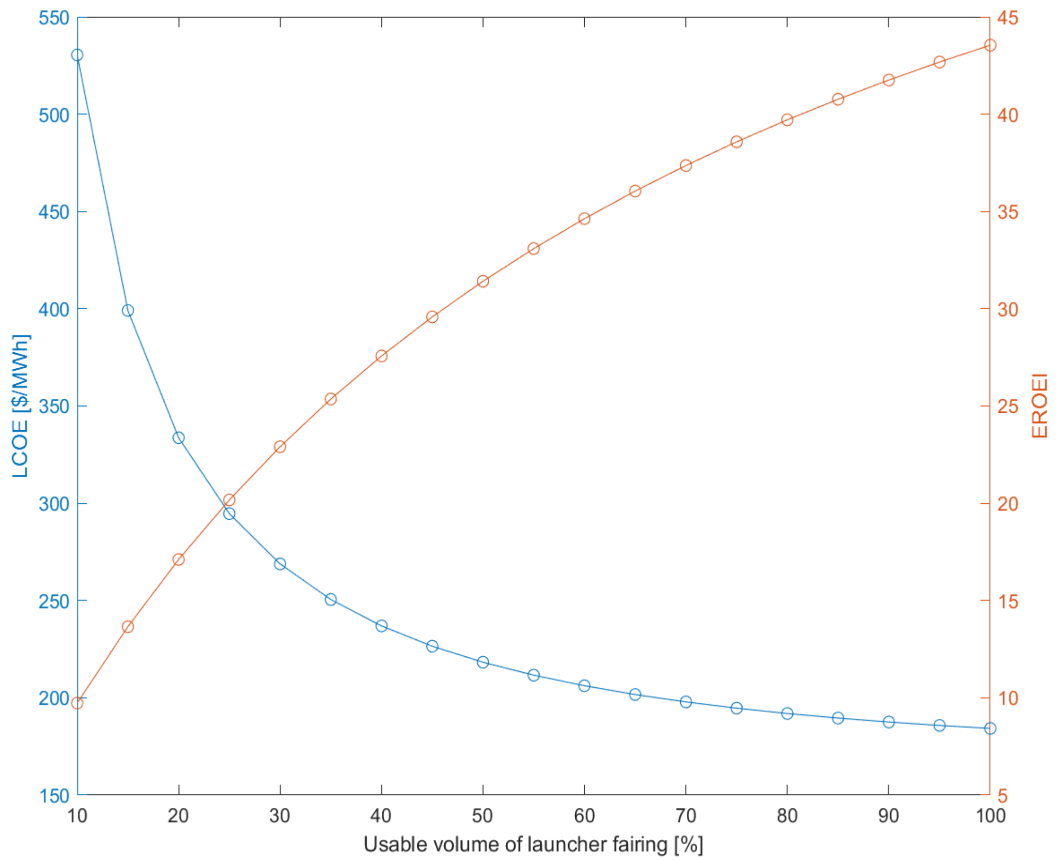
Solution – Low-Fidelity analysis results

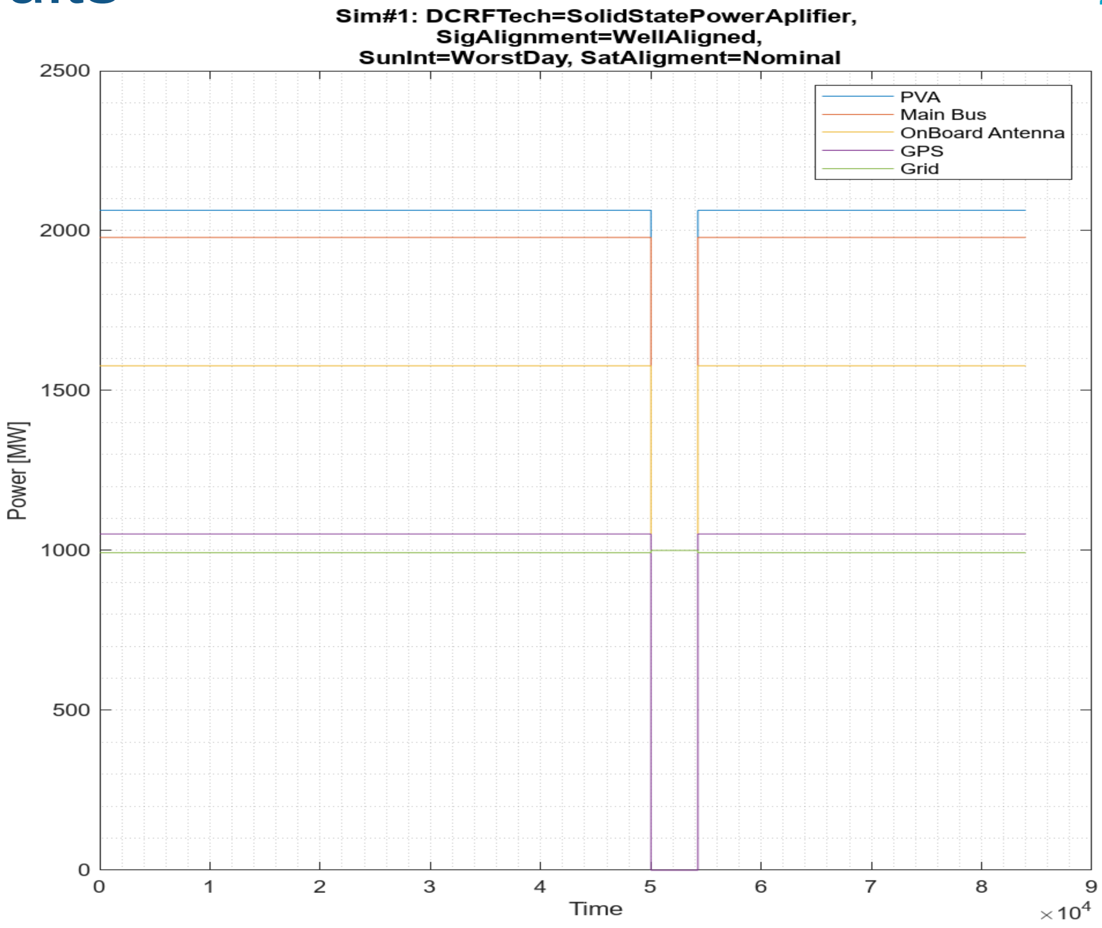




- Scatter plot of results obtained with different input parameters combination
- Multiplicity of the 3 main areas combination solutions obtained during a simulation

Solution – High-Fidelity analysis results





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