



Enabling MBSE with Simulation to perform System Analysis for Space-Based Solar-Power

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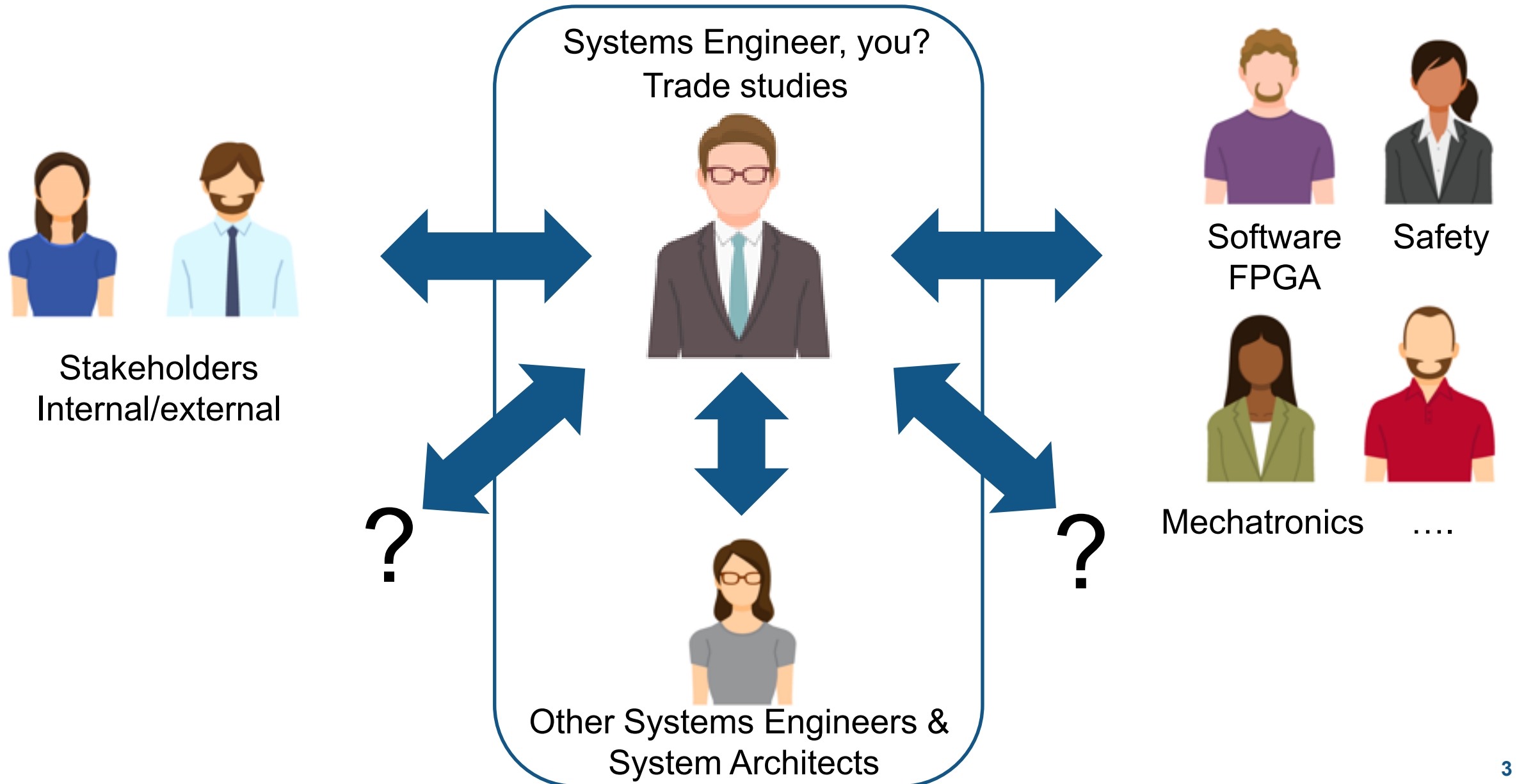


Acknowledgement

This work has been done in collaboration with
Thales Alenia Space Italy:

Serena Brizio, Lorenzo Guarino, Umberto Di Tommaso

My presentation in context

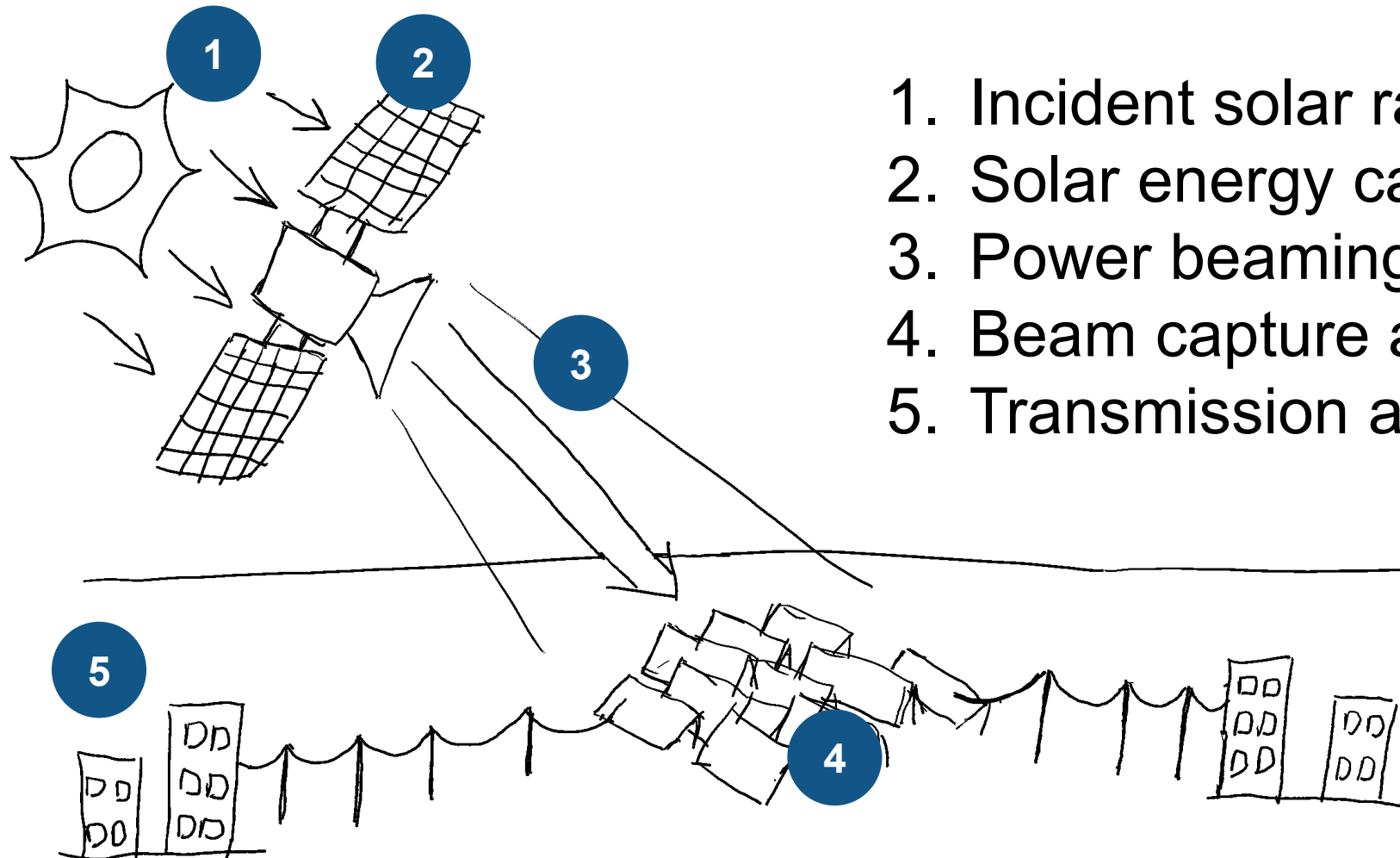


Agenda

- What is Space-Based Solar-Power?
- What are the main challenges/needs?
- Solution
 - Process/methodology
 - Bridge between Capella and System Composer
 - Analysis Workflow
- Outcomes & Concluding Remarks
- Q&A

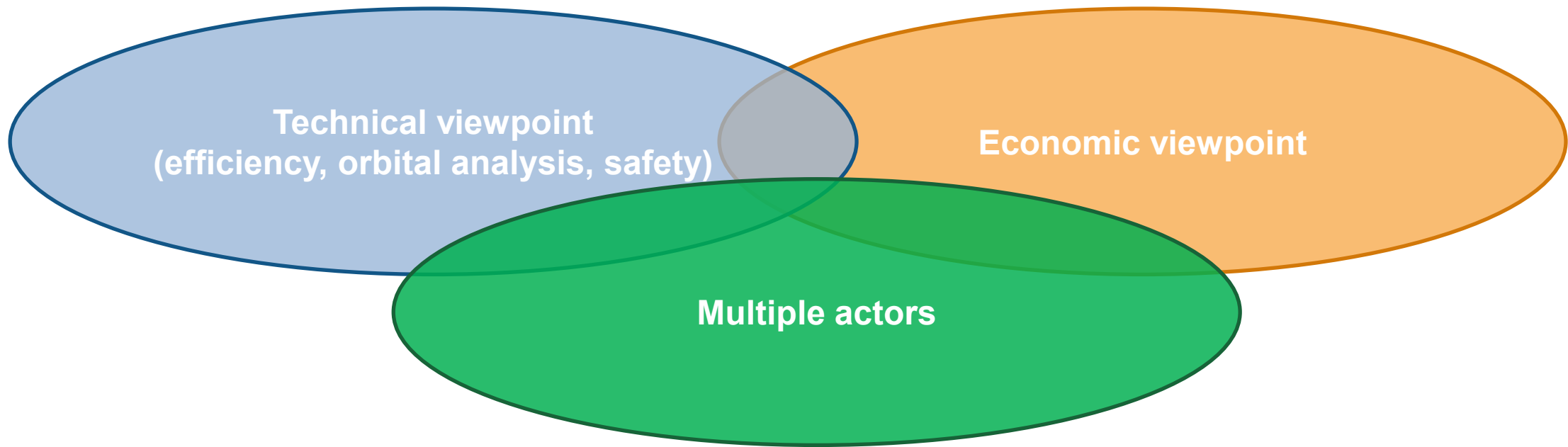
What is Space-Based Solar-Power about?

- 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

What are the main challenges/needs?

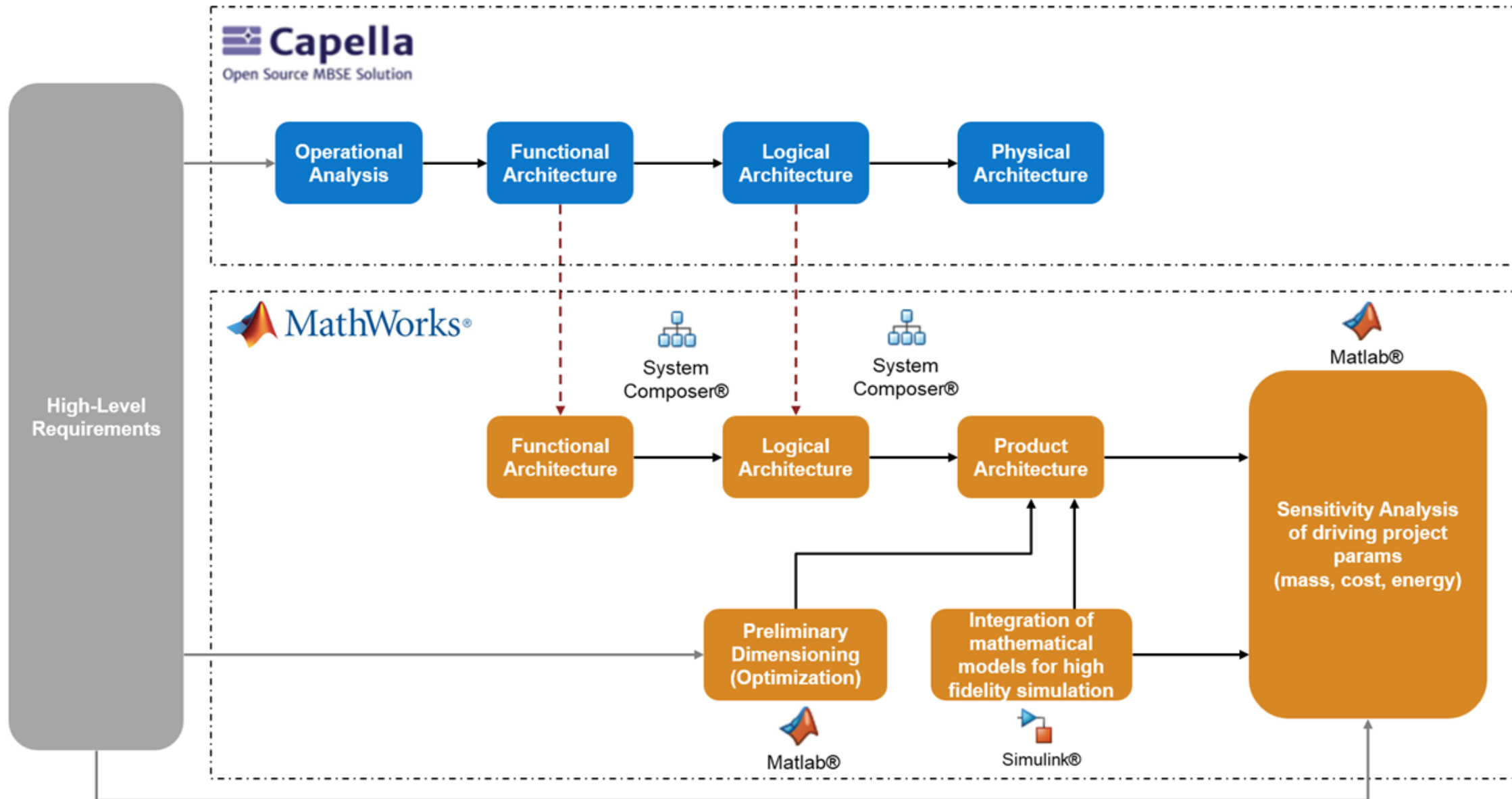


Static point of view (Capella)



Dynamic point of view
(System Composer,
Simulink)

Solution - Process/methodology



Solution - Bridge between Capella and System Composer

Satellite

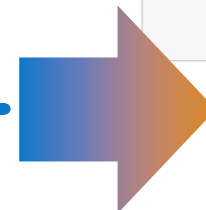
Capella Model

System Composer

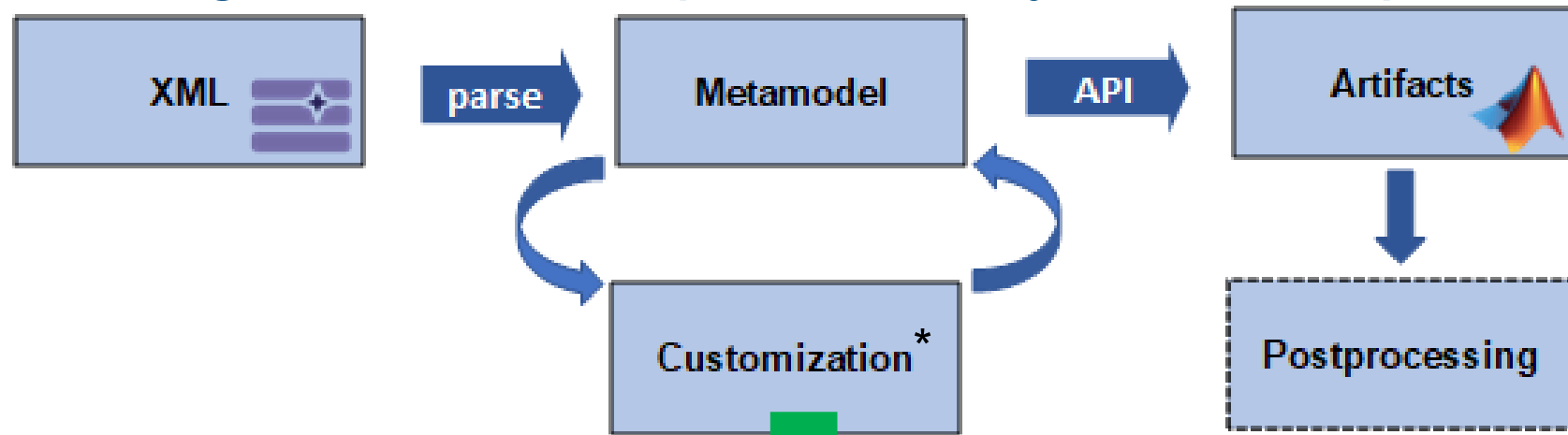
Product Architecture

Ground station

Logical Architecture

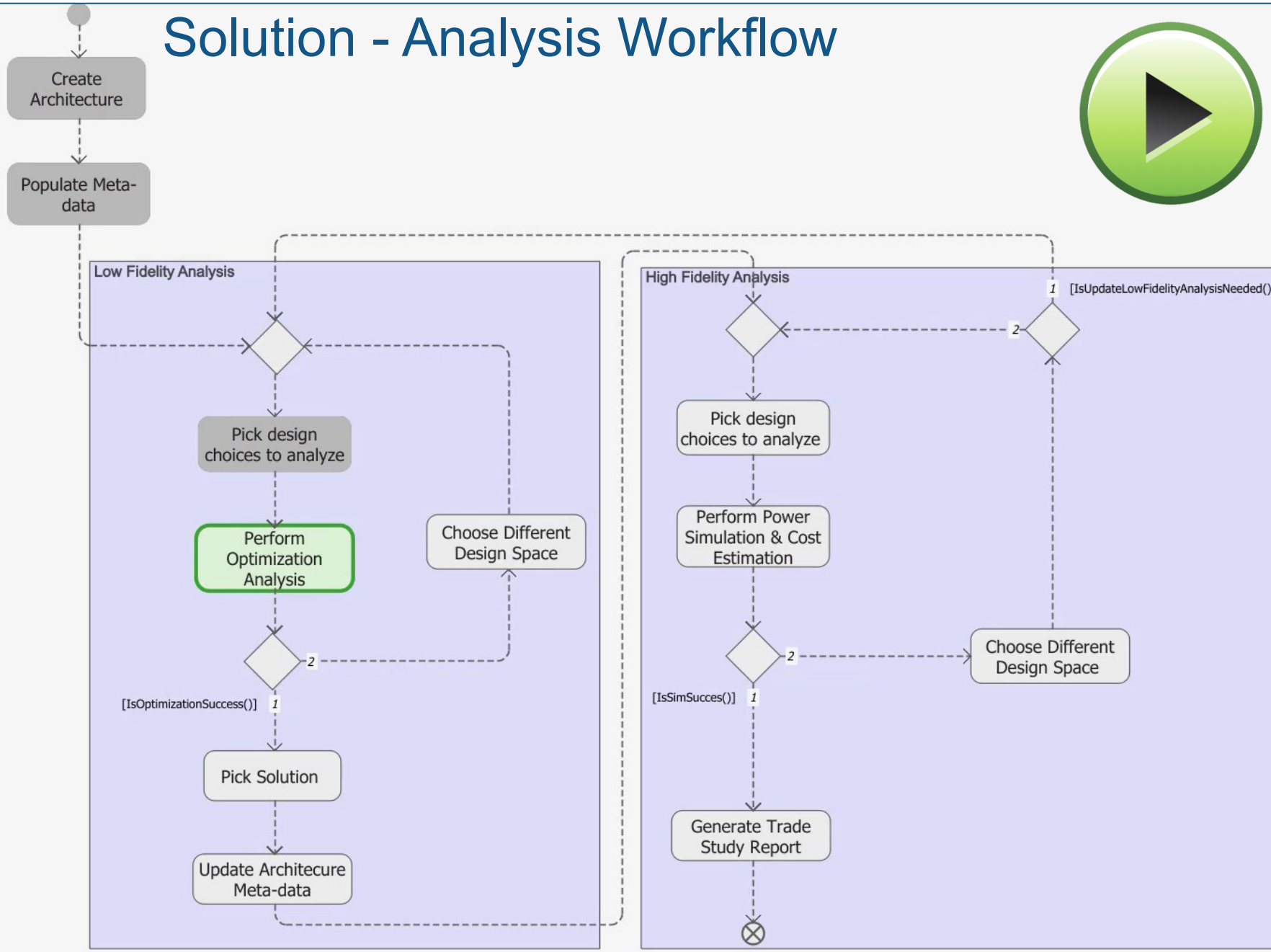


Solution - Bridge between Capella and System Composer



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

Solution - Analysis Workflow



Solution - Analysis Workflow

3 x 3 x 2 = 18 unique variant combinations

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

Tunable Parameter List

- ☐ CellTechnology
- ☐ GroundPowerStationLocation
- ☐ TransmissionFrequency

Analysis Type: Low Fidelity

Generate Sim Report: No

Optimization Weights List

Parameter Name	Parameter Value
WGoundStation	1
WAntenna	30
WSolarPanel	30

Target Power [GW]: 1

Define Fixed Parameter Values

Parameter Name	Parameter Selection	Parameter Value
CellTechnology	Perovskite	[29% 0.3Kg/m²]
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

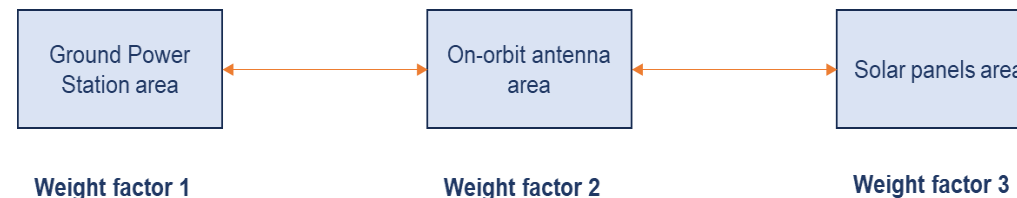
Fixed Parameters parameters:

- CellTechnology

#	Ground Power Station Lat (°)	Transmission Frequency (GHz)	Cell Efficiency (%)	Ground Power Station Area (Km²)	Antenna Area (Km²)	Solar Panel Area (Km²)	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

$$\text{objective} = w1 \cdot x(1) + w2 \cdot x(2) + w3 \cdot x(3)$$



Solution - Analysis Workflow

High Fidelity Analysis

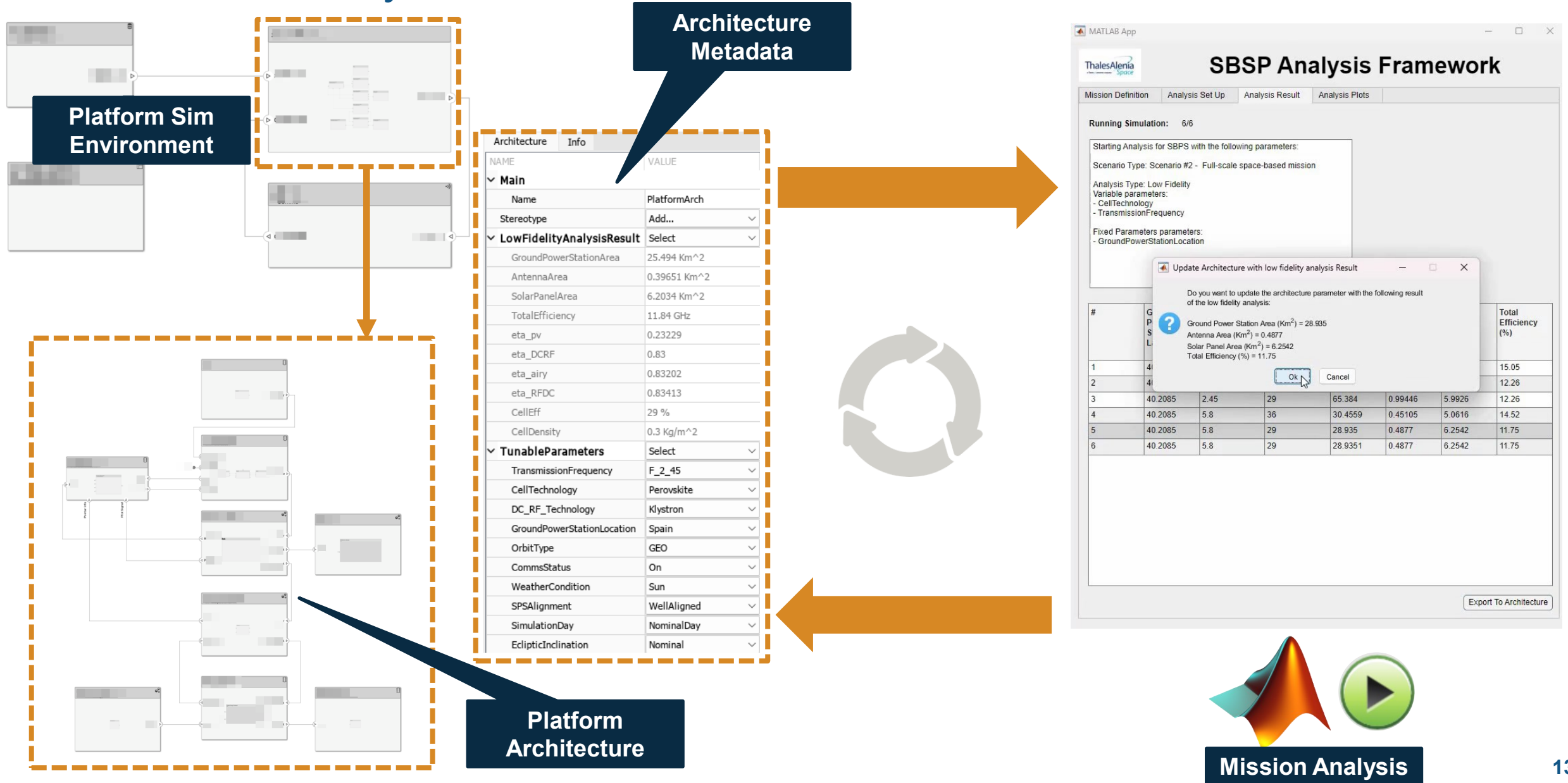
- Objective:
 - High-fidelity power simulations in various mission scenarios
 - Preliminary mass and cost estimation
- Design Choices
 - (3) DC-RF Technology
 - (2) Simulation Day
 - (2) Ecliptic inclination
 - (2) SPS Alignment

The screenshot shows the 'SBSP Analysis Framework' software interface. It has tabs for 'Mission Definition', 'Analysis Set Up', 'Analysis Result', and 'Analysis Plots'. The 'Analysis Set Up' tab is active, showing 'Define Multisimulation Parameters & Settings'. A blue box highlights the 'Tunable Parameter List' which includes checkboxes for 'DC_RF_Technology', 'EclipticInclination', 'SPSAlignment', and 'SimulationDay'. To the right, 'Analysis Type' is set to 'High Fidelity' and 'Generate Sim Report' is set to 'No'. Below this is a table for 'Define Fixed Parameter Values' with columns for Parameter Name, Parameter Selection, and Parameter Value. The table lists 'DC_RF_Technology' (SolidStatePowerAplifier, [60W 0.001Kg]), 'EclipticInclination' (Nominal, Nominal), 'SPSAlignment' (WellAligned, WellAligned), and 'SimulationDay' (NominalDay, NominalDay). A 'Run' button is at the bottom right.

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

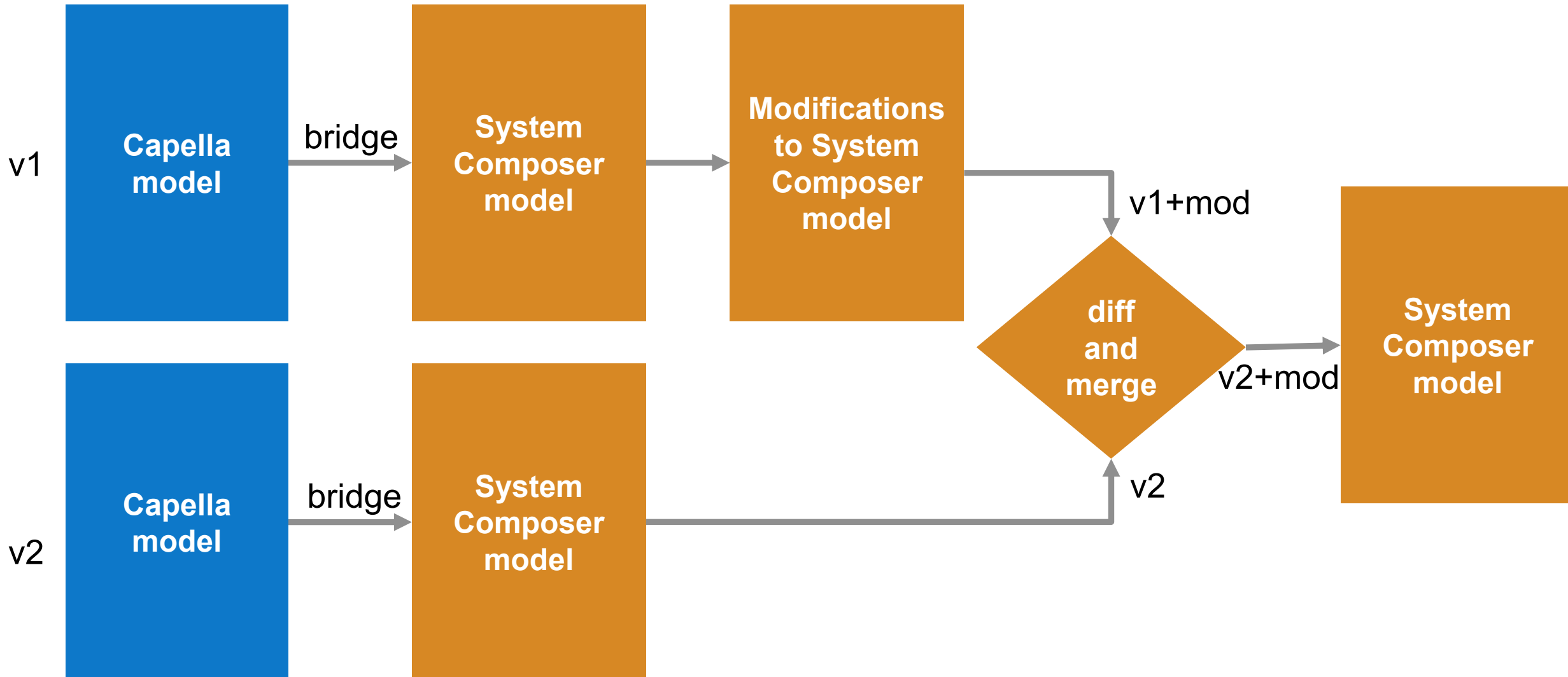
3 x 2 x 2 x 2 = 24 unique variant combinations

Solution - Analysis Workflow



Solution - Bridge between Capella and System Composer

Digital continuity

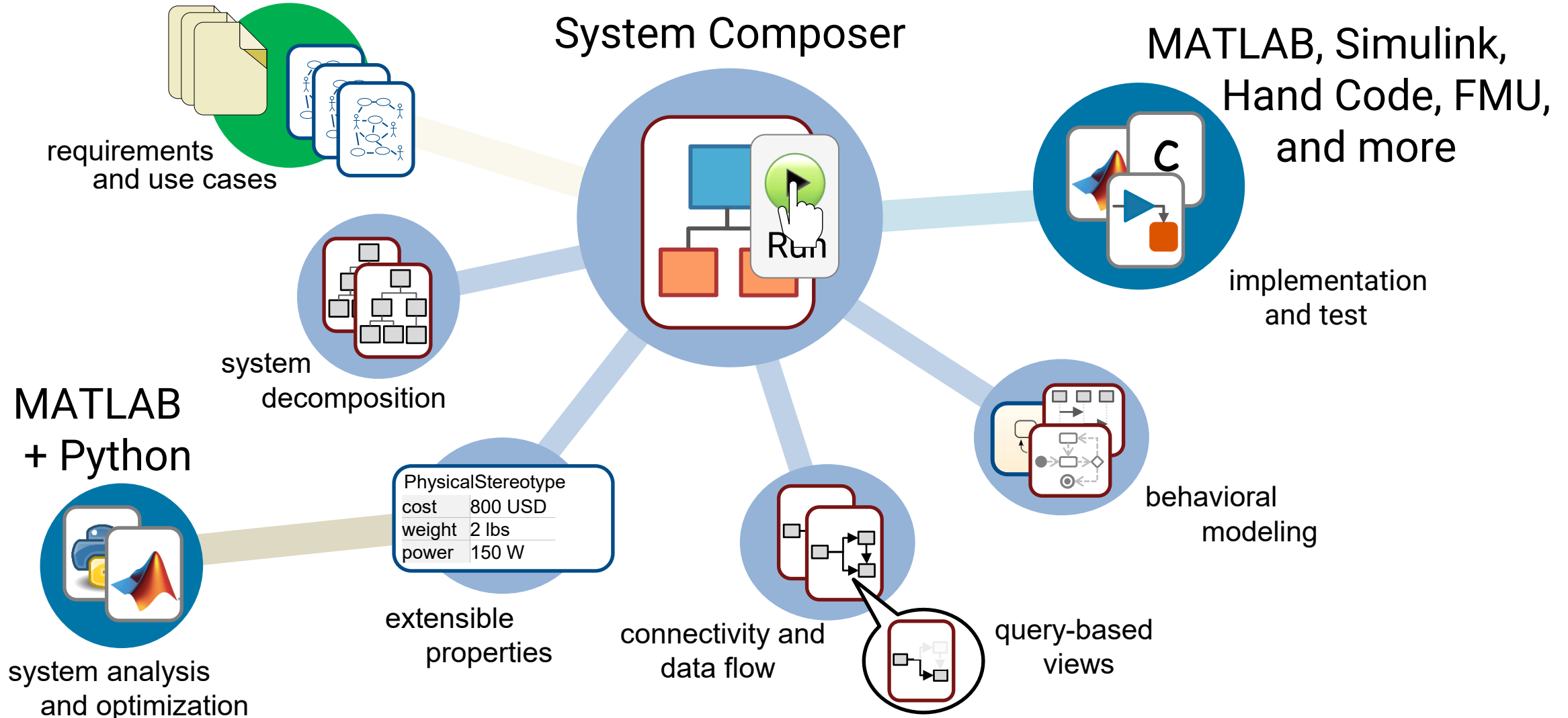


Outcomes

- **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

Model-Based Systems Engineering at MathWorks

Managing Requirements





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digital handouts



Q&A

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