MathWorks Model-Based Systems Engineering

Practical use-cases → bridging the gap

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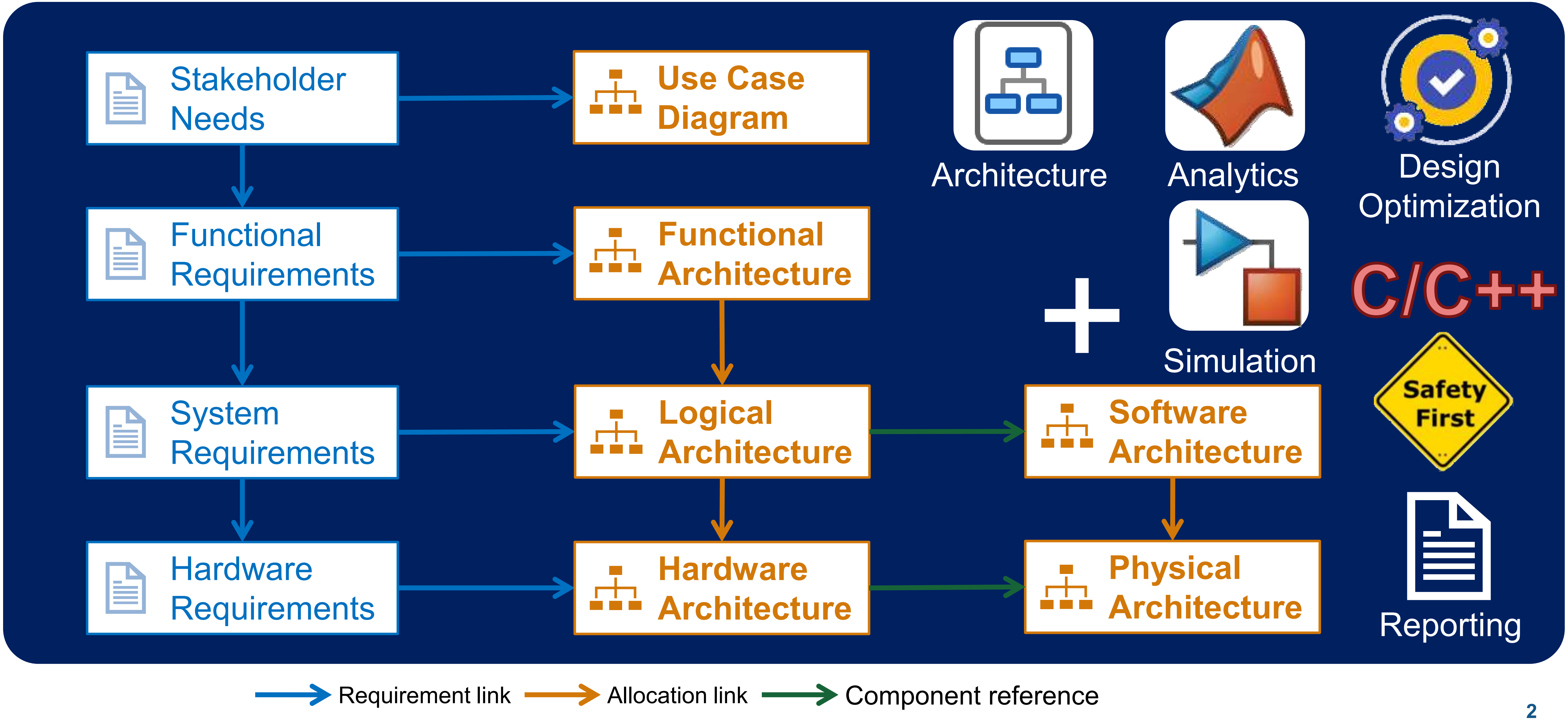
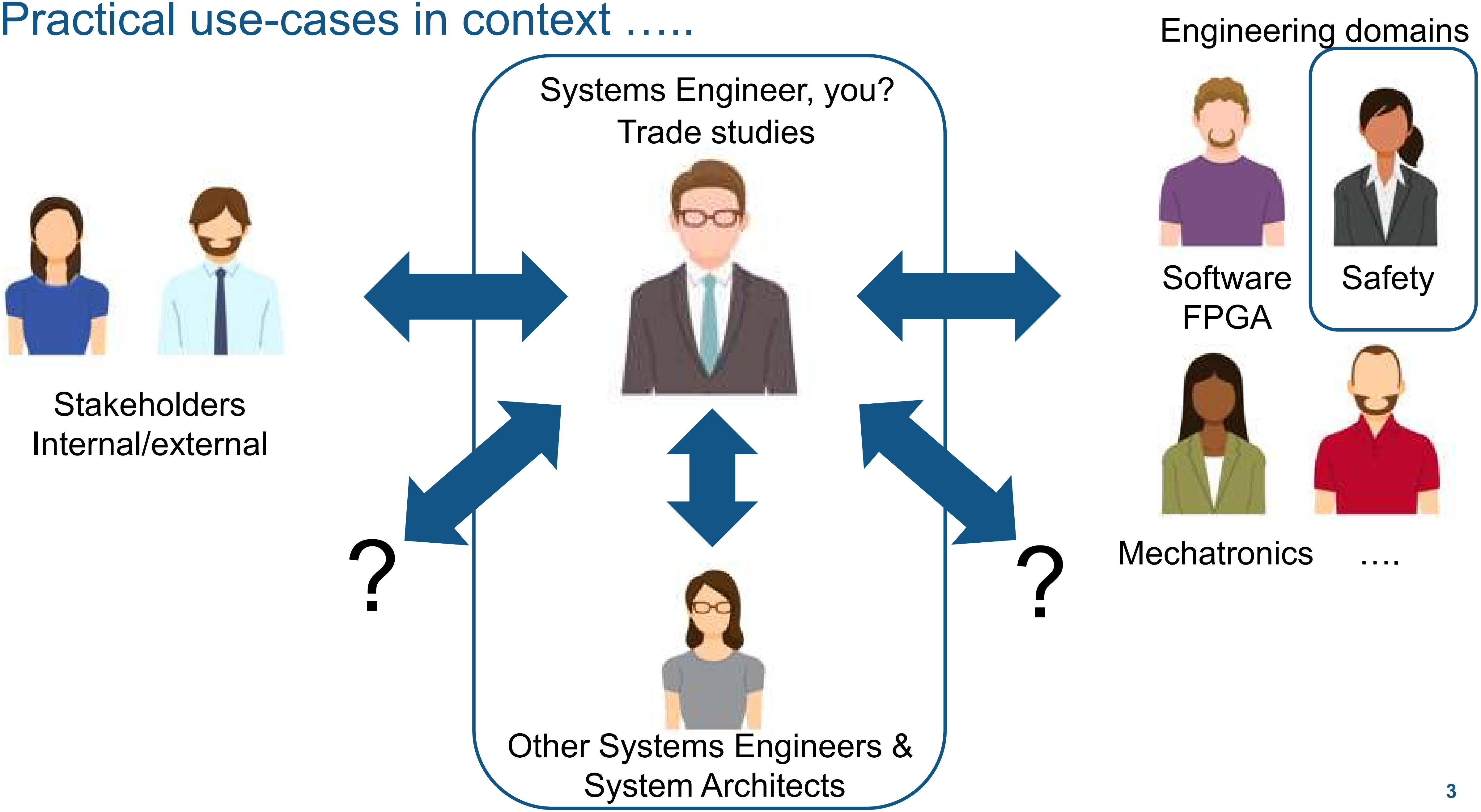
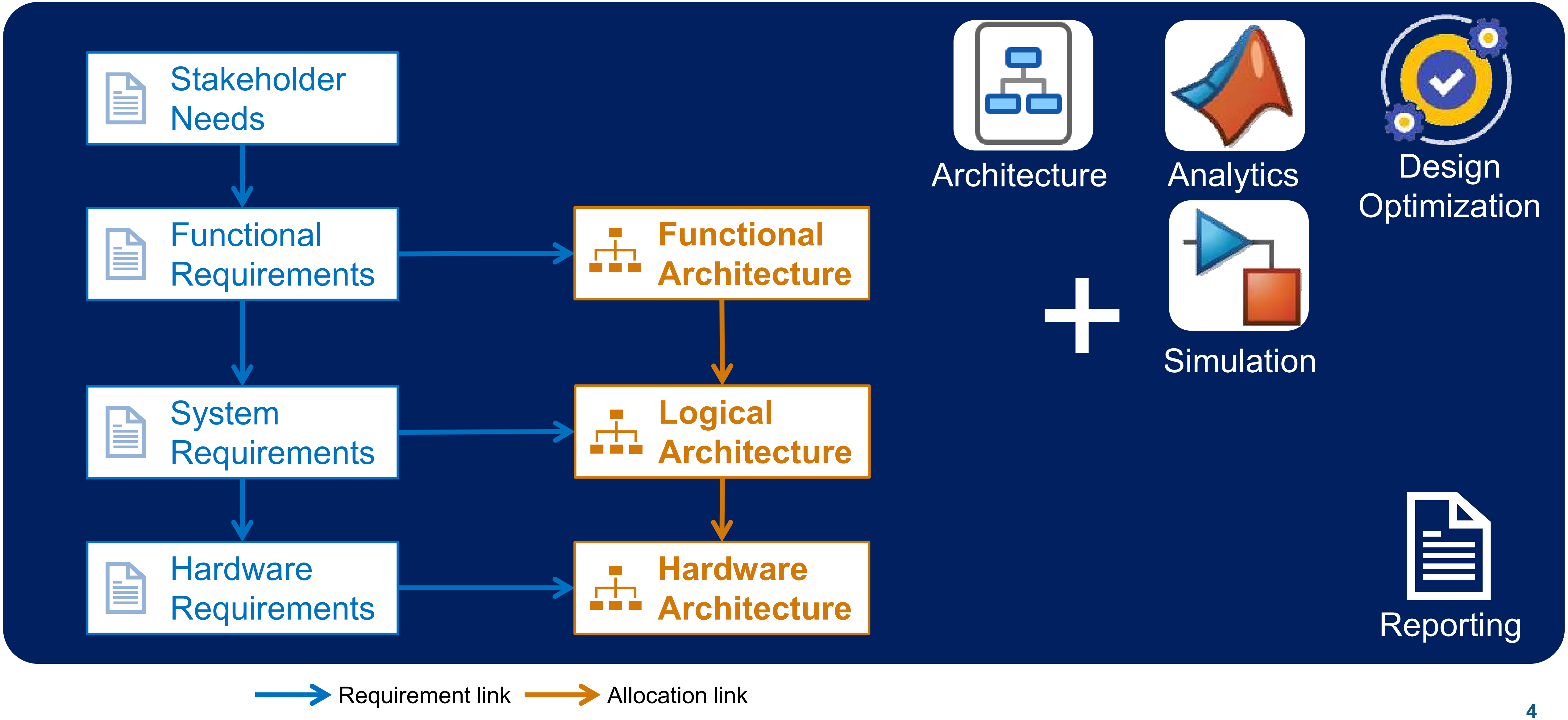
MathWorks Model-Based Systems Engineering



Practical use-cases in context …..



MathWorks Model-Based Systems Engineering, **Trade Studies**



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

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Acknowledgement

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Thales Alenia Space Italy:

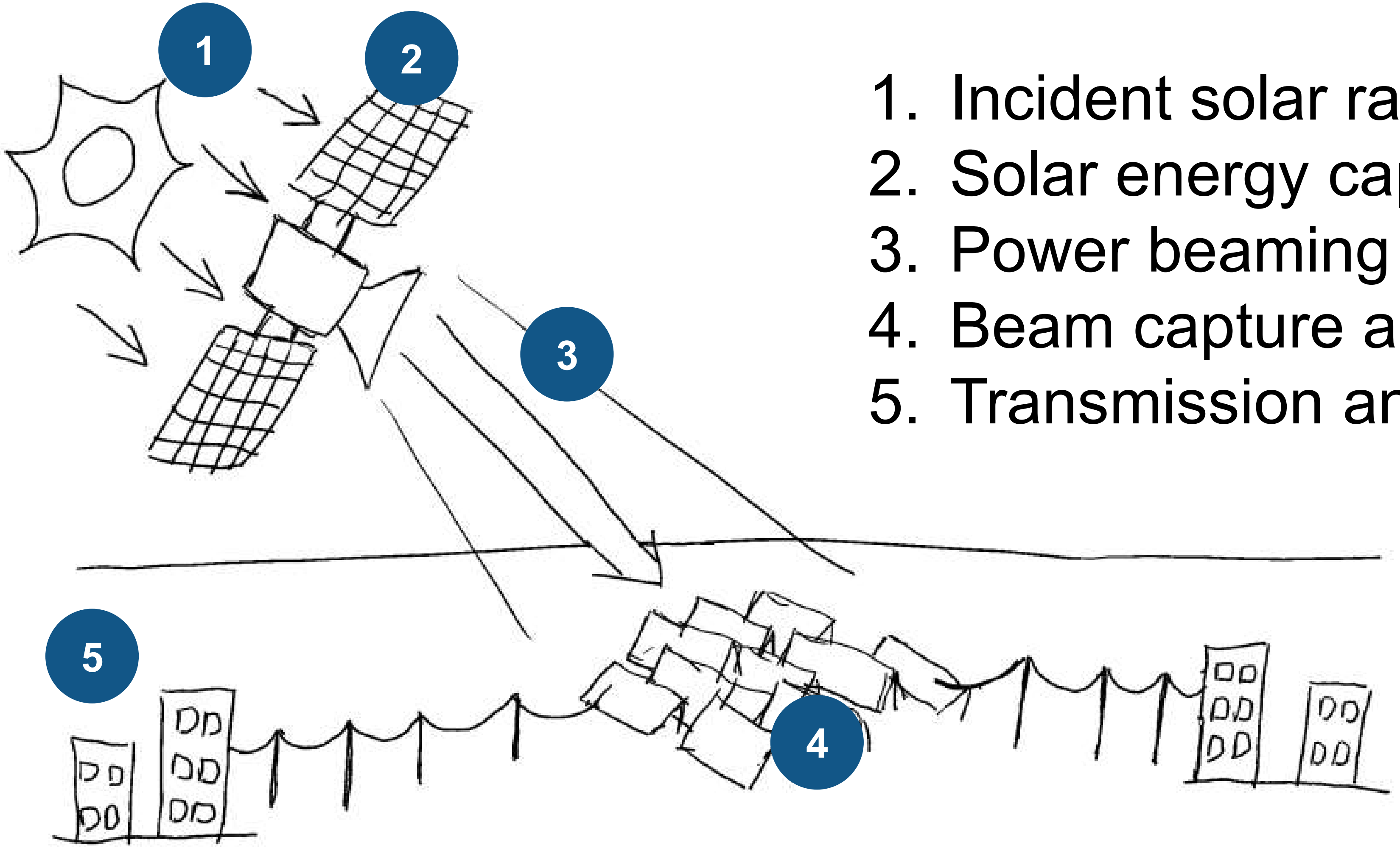
Serena Brizio, Lorenzo Guarino, Umberto Di Tommaso

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

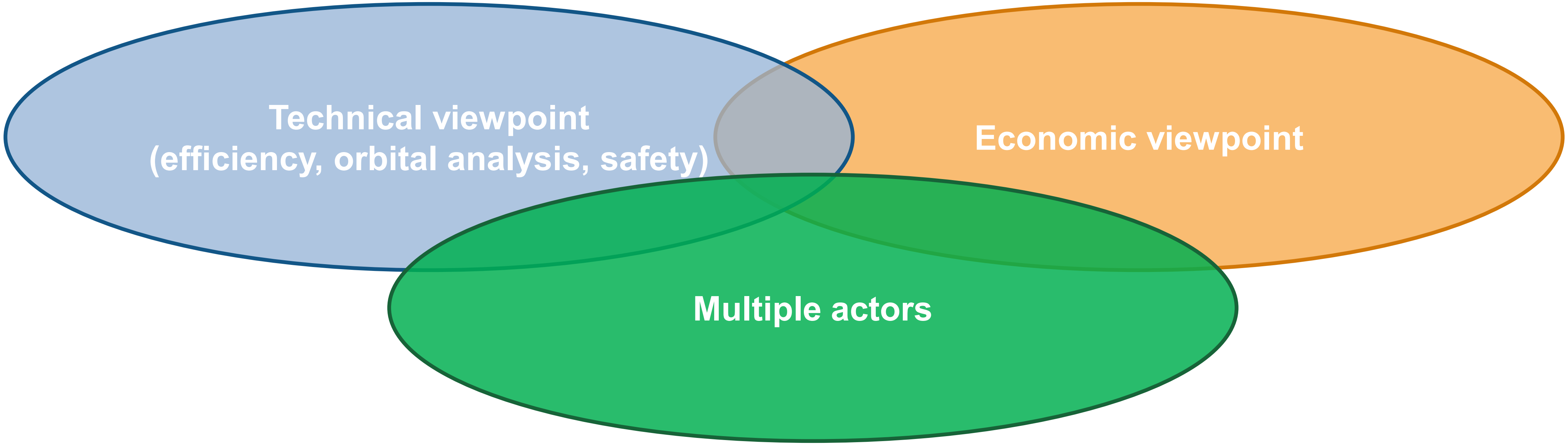
What is Space-Based Solar-Power (SBSP) about?

- 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

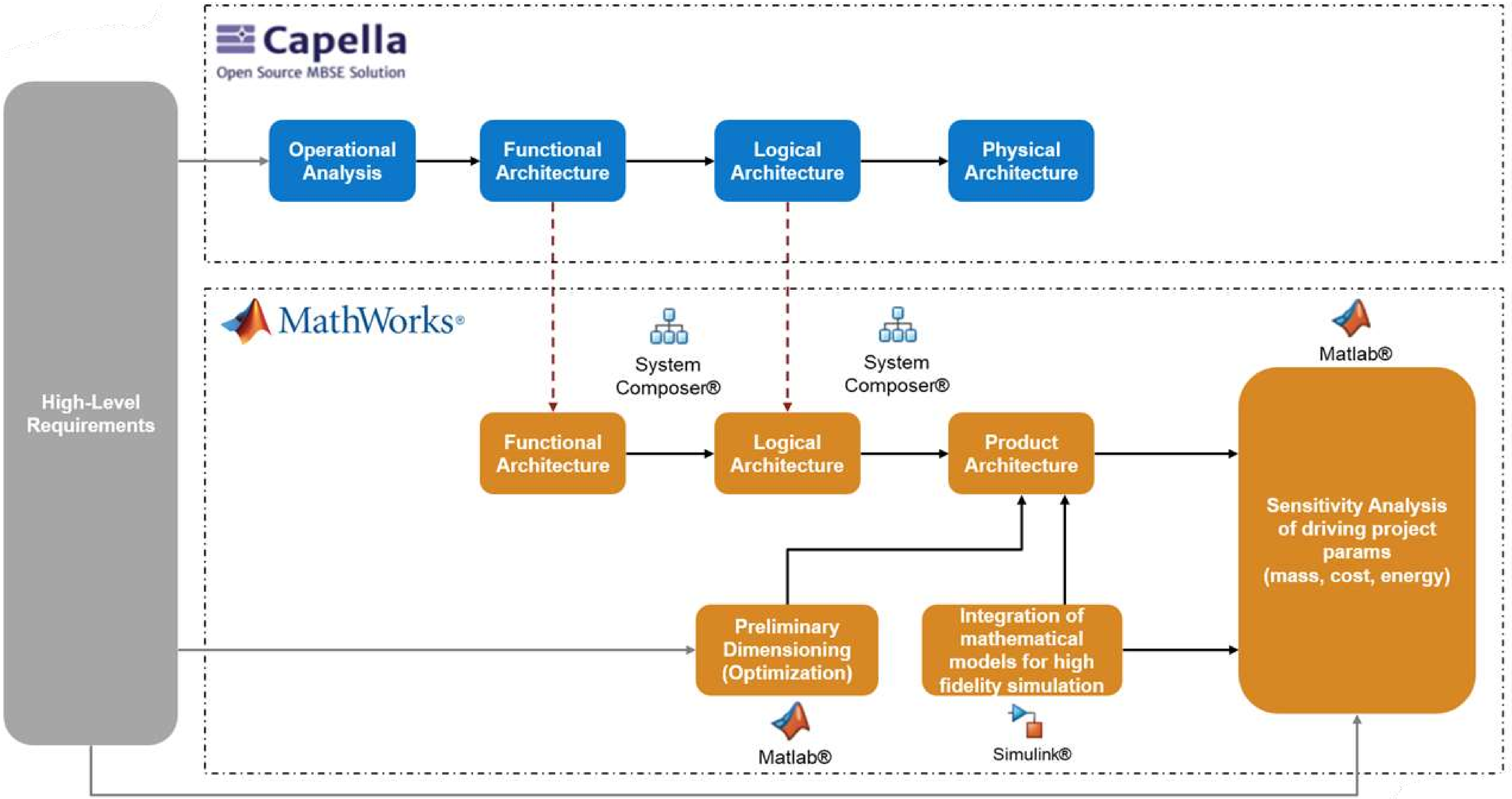
What are the main challenges/needs?



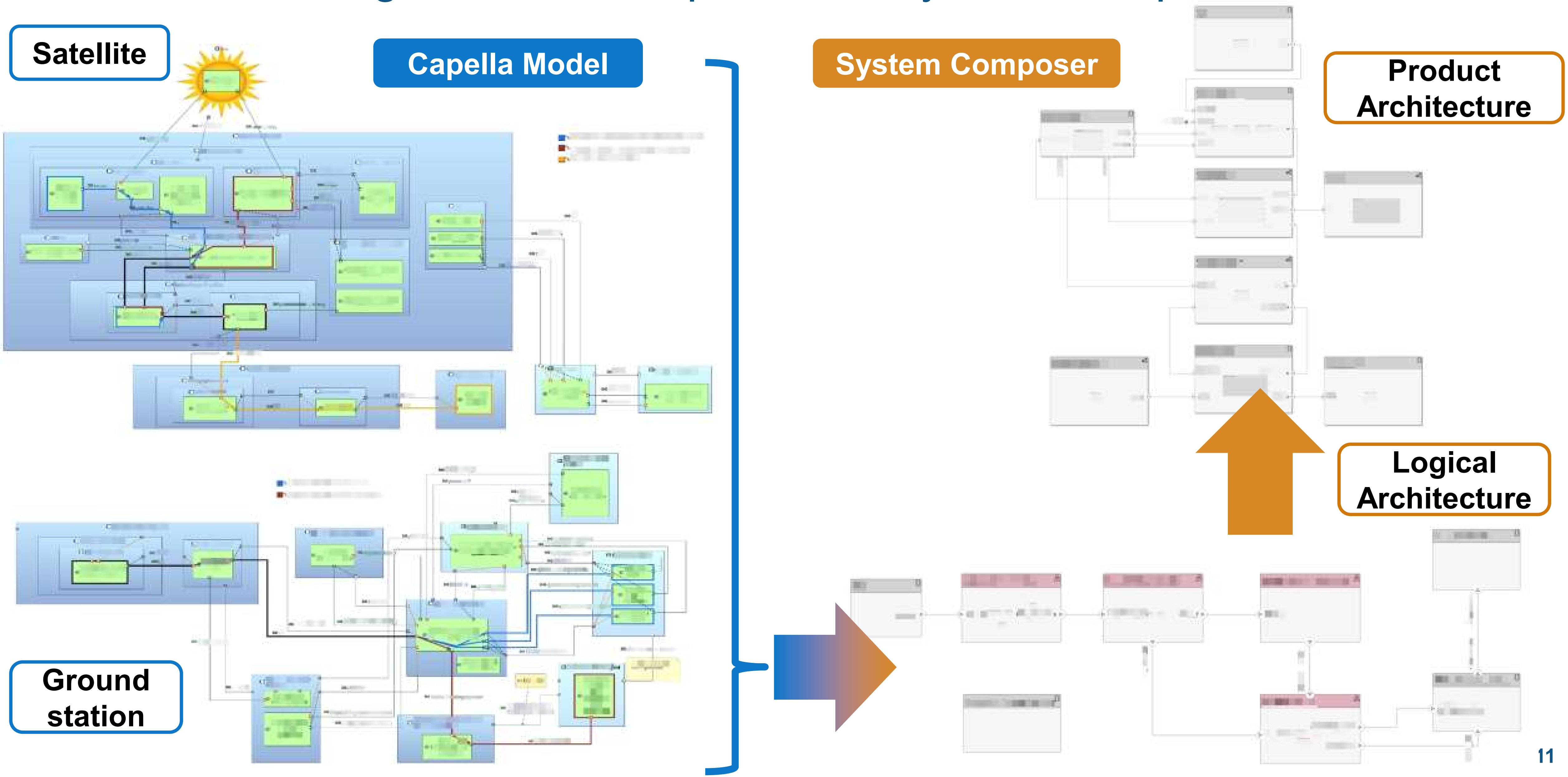
Static point of view

Dynamic point of view

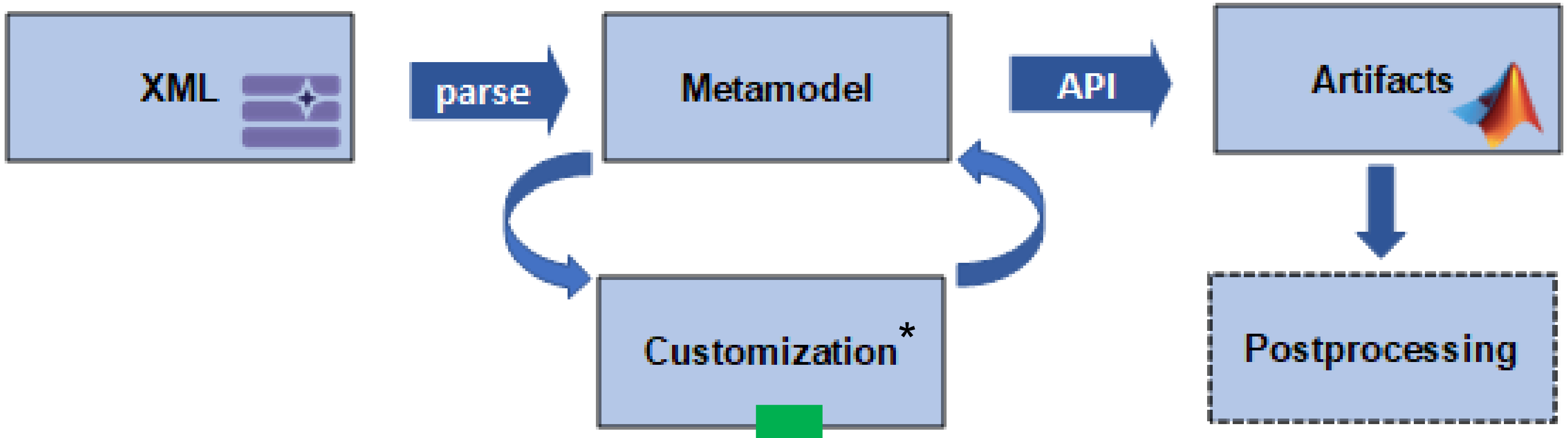
Solution - Process/methodology



Solution - Bridge between Capella and System Composer



Solution - Bridge between Capella and System Composer

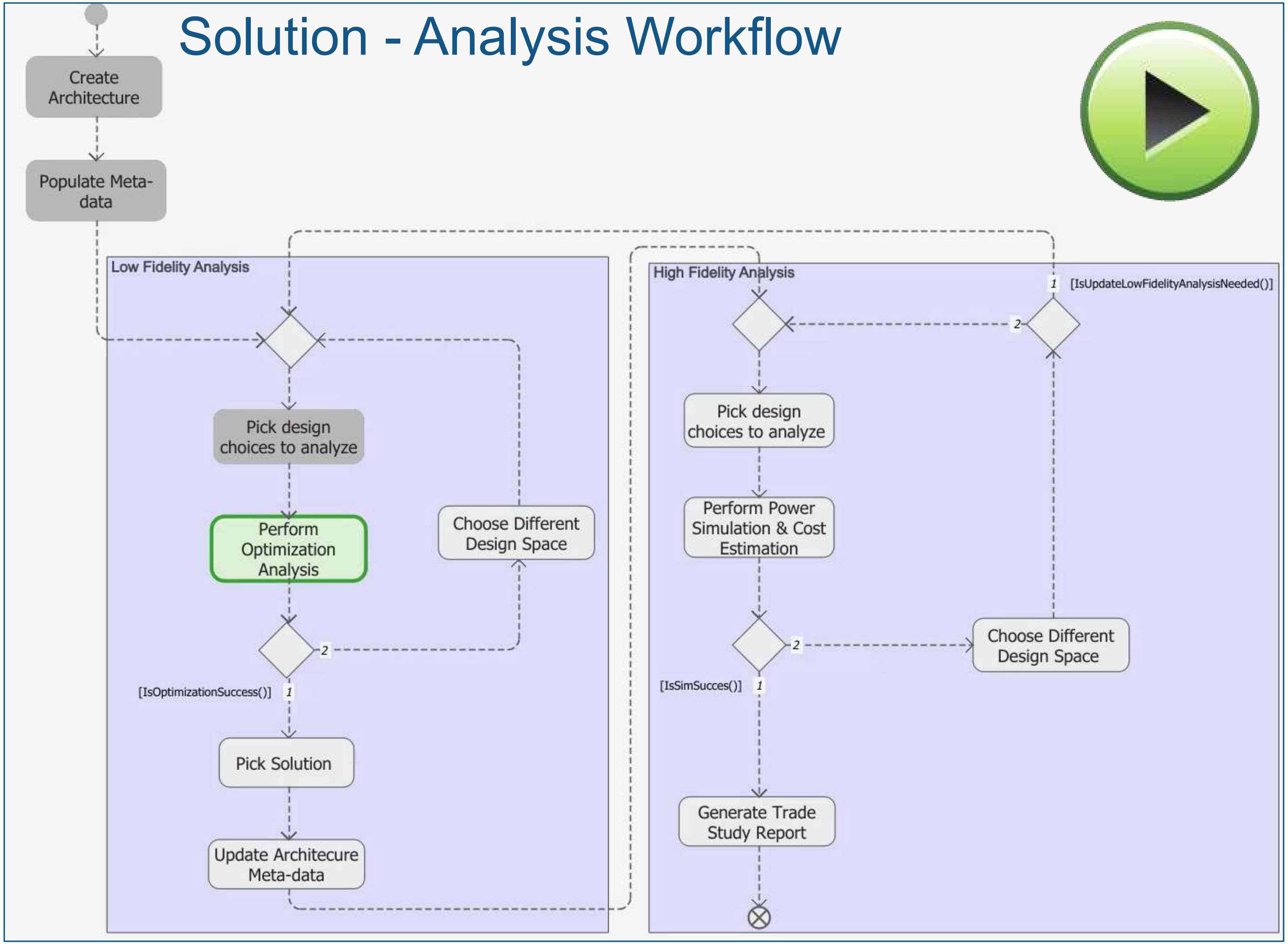


Capella ➔	➔ System Composer
LogicalArchitecture	Architecture model
LogicalComponent	Architecture model
ComponentExchange	Root-level port with composite interface
FunctionalExchange	Connector
ExchangeItem	Interface item
Datatype	Interface item type
Class	Composite interface

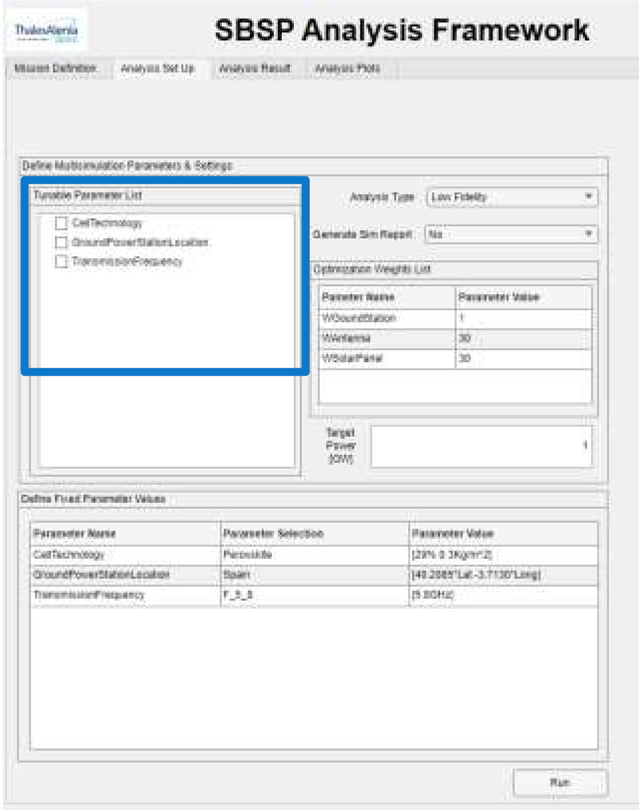
[Full Article: Creating a Bridge Between Capella and System Composer]

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

Solution - Analysis Workflow



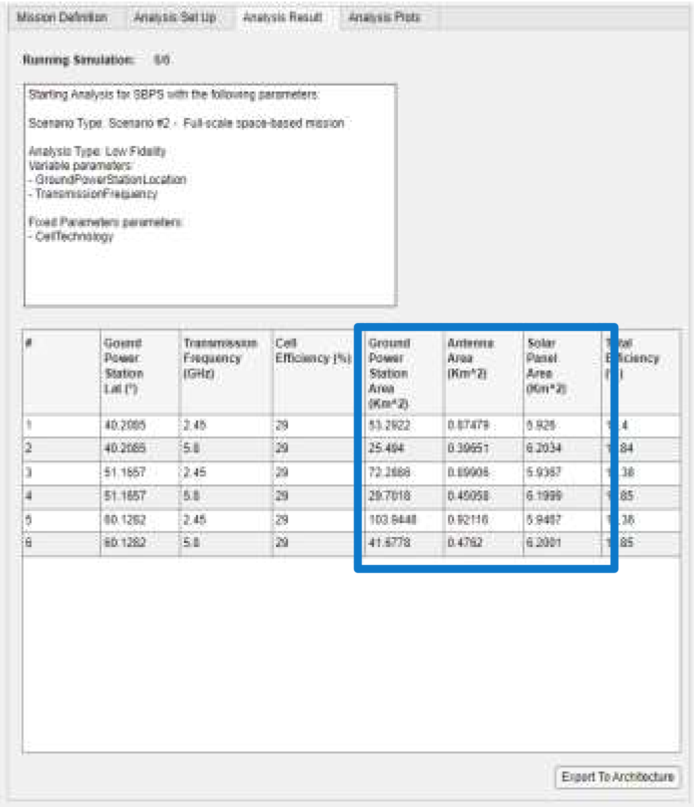
Solution - Analysis Workflow



<u>Low Fidelity Analysis</u>

- Objective: Find optimal combination of the Photovoltaic (PV) area, antenna area, and GPS area

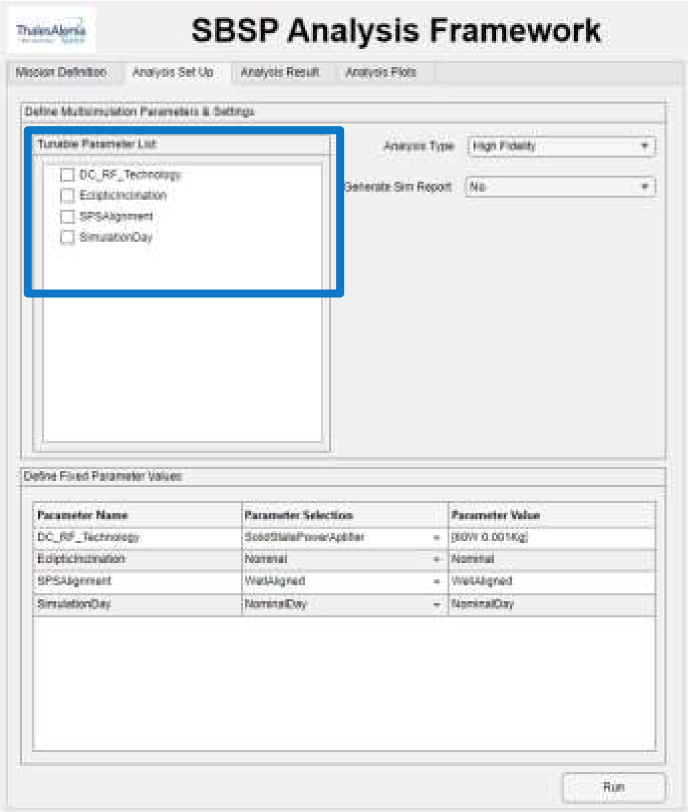
- Design Choices
  - (3) Cell technology
  - (3) Ground Station Location
  - (2) Transmission Frequency



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

3 x 3 x 2 = 18 unique variant combinations

Solution - Analysis Workflow



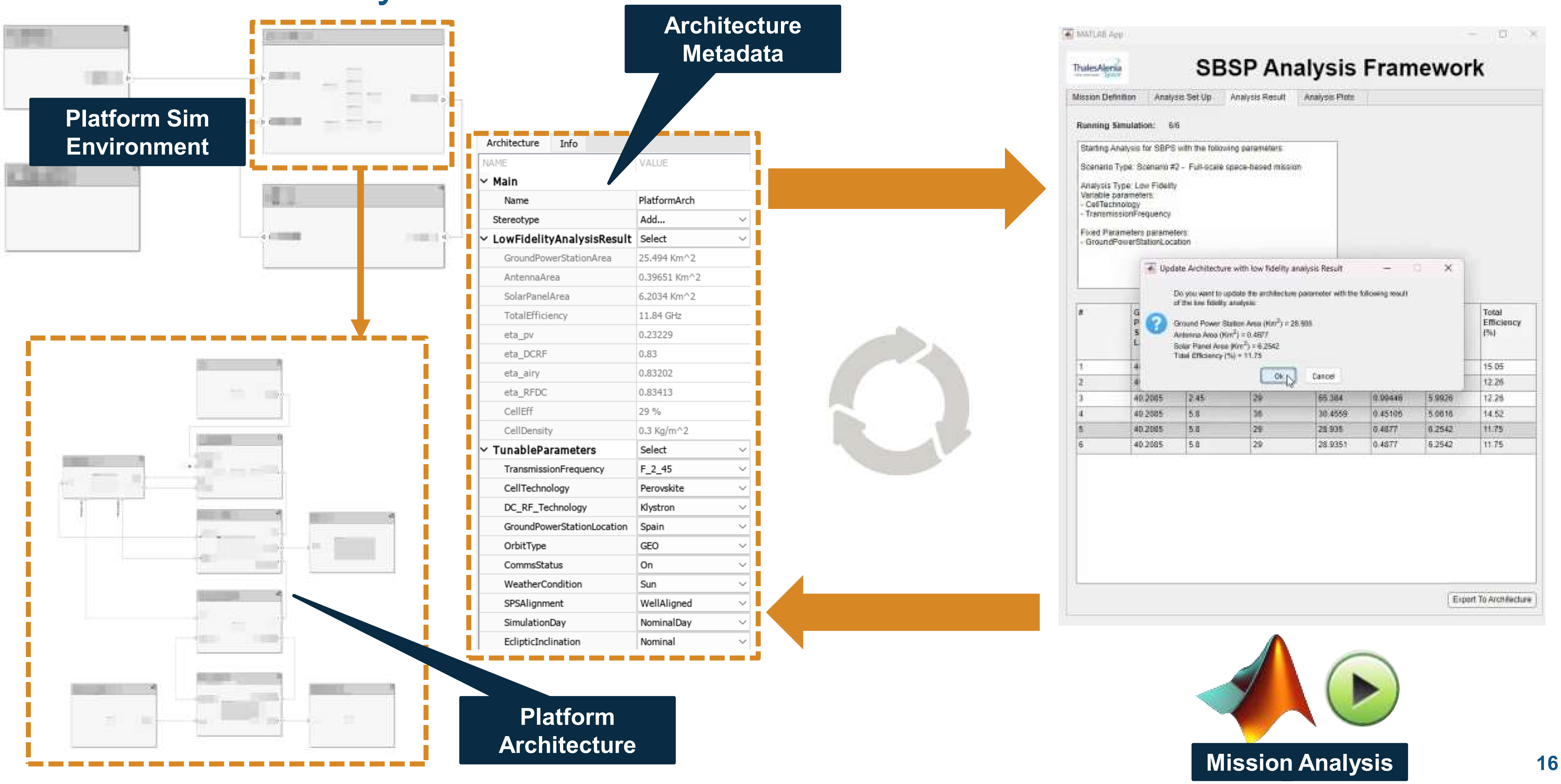
<u>High Fidelity Analysis</u>

- 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

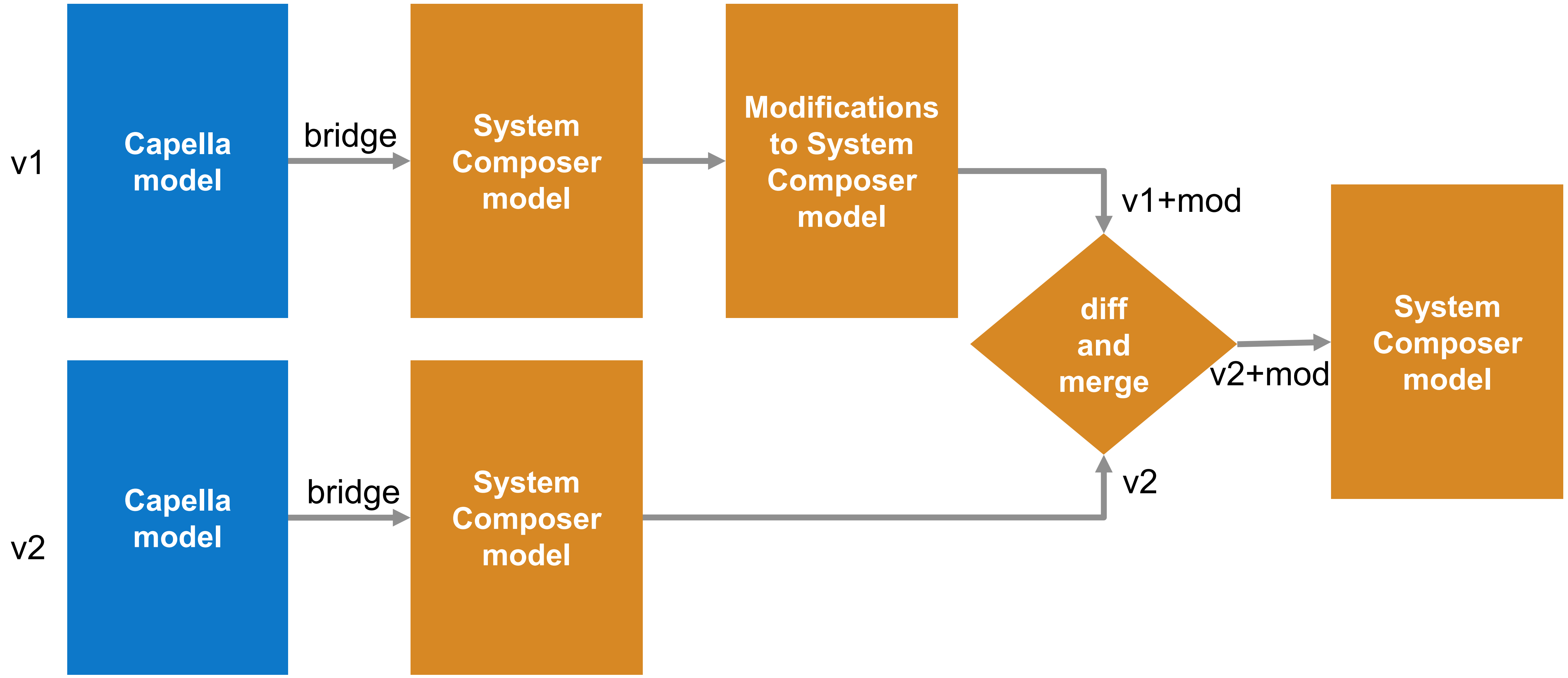
3 x 2 x 2 x 2 = 24 unique variant combinations

Solution - Analysis Workflow



Solution - Bridge between Capella and System Composer

Digital continuity



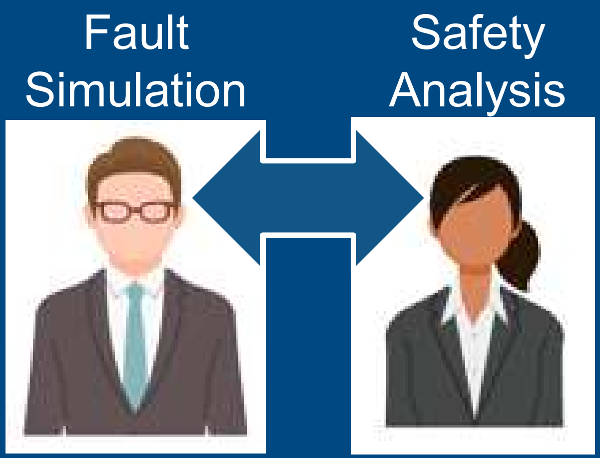
Outcomes

- **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

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 .



Safety Analysis as an extension of MBSE

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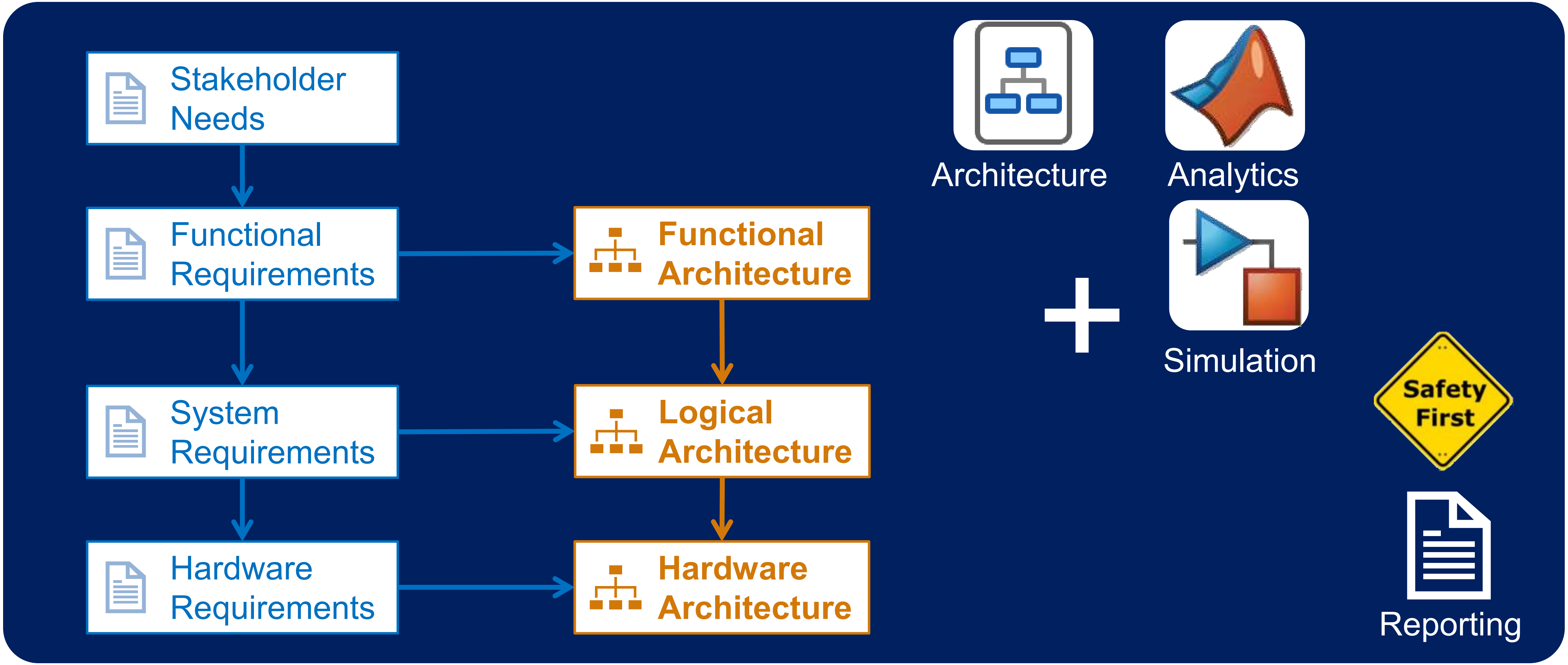
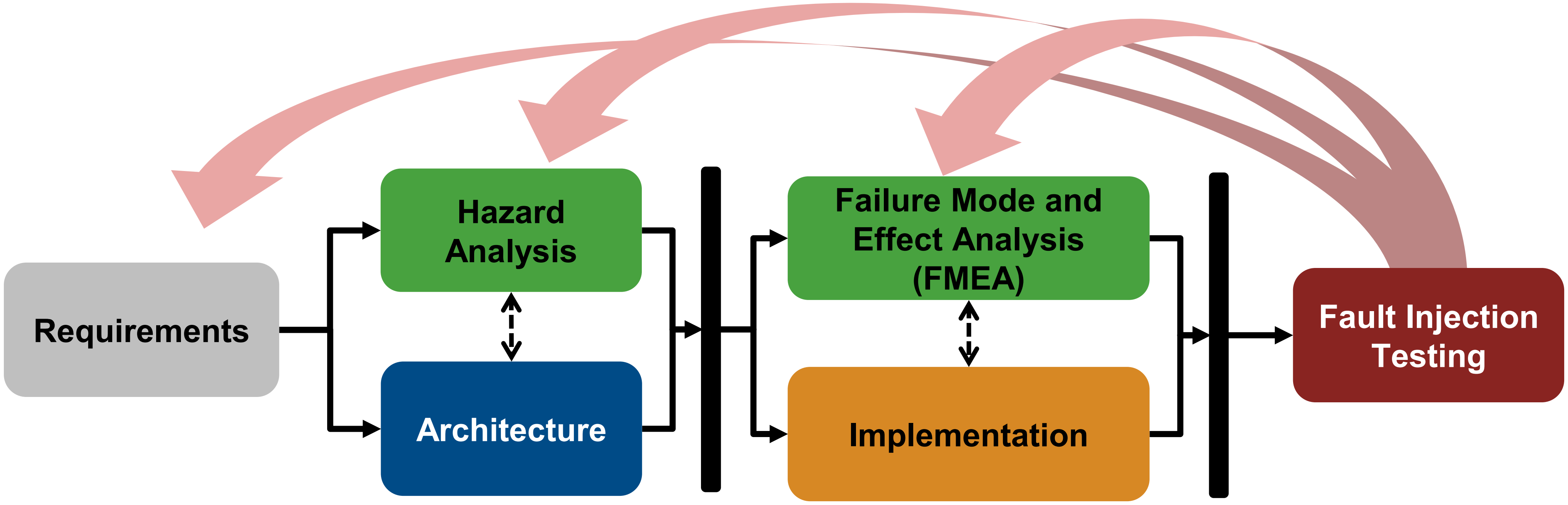
MathWorks Model-Based Systems Engineering, **Safety Engineering**

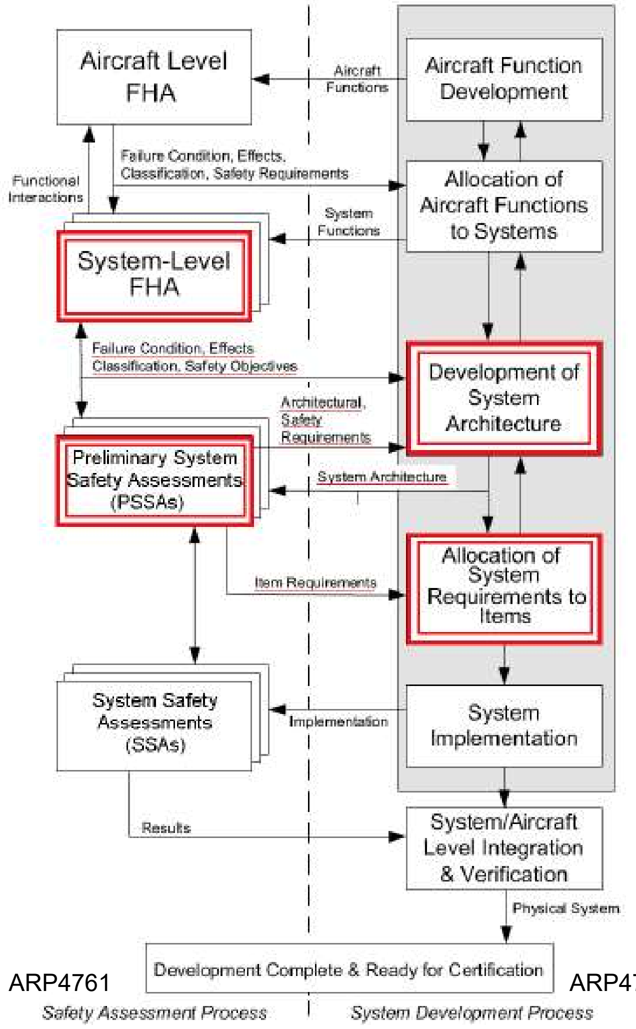


Requirement link Allocation link

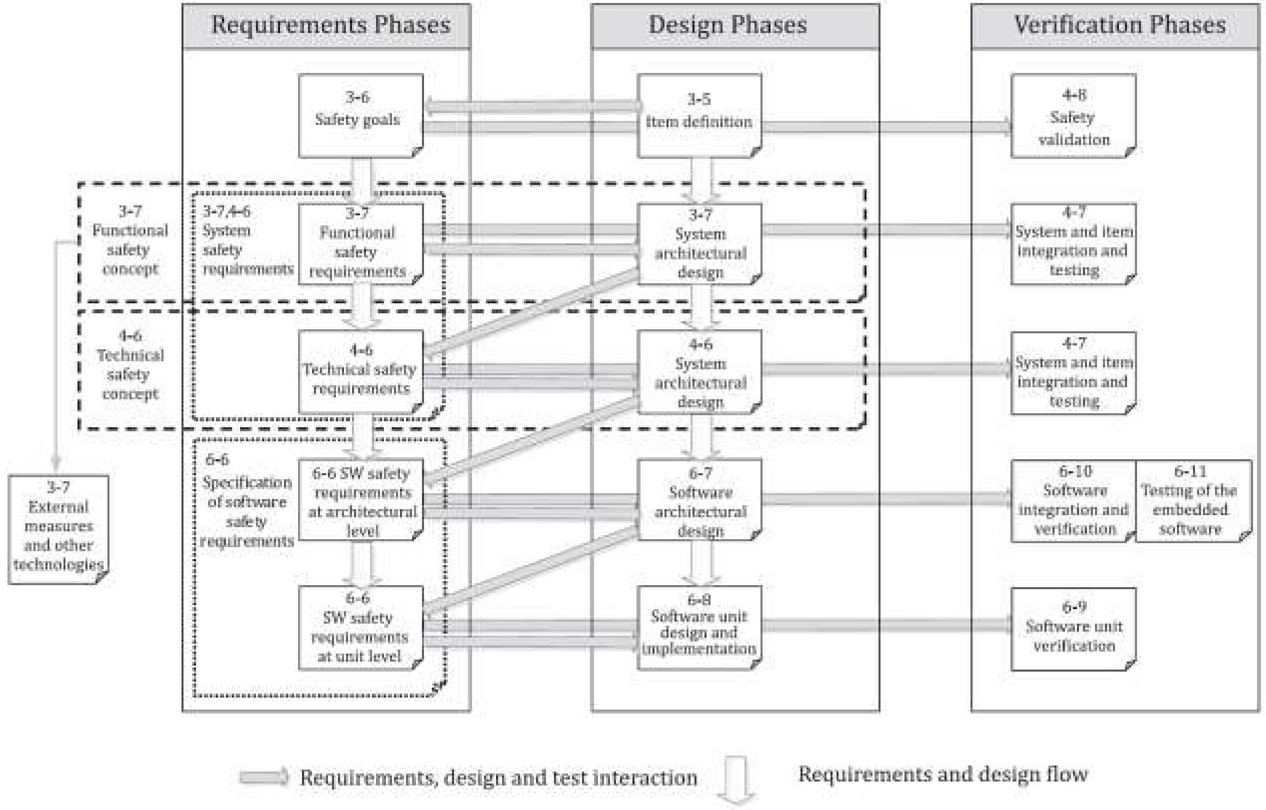
Safety Analysis, Detection / Mitigation and Verification are key activities in the design of engineered systems



Safety & Design are parallel activities – Standards Example



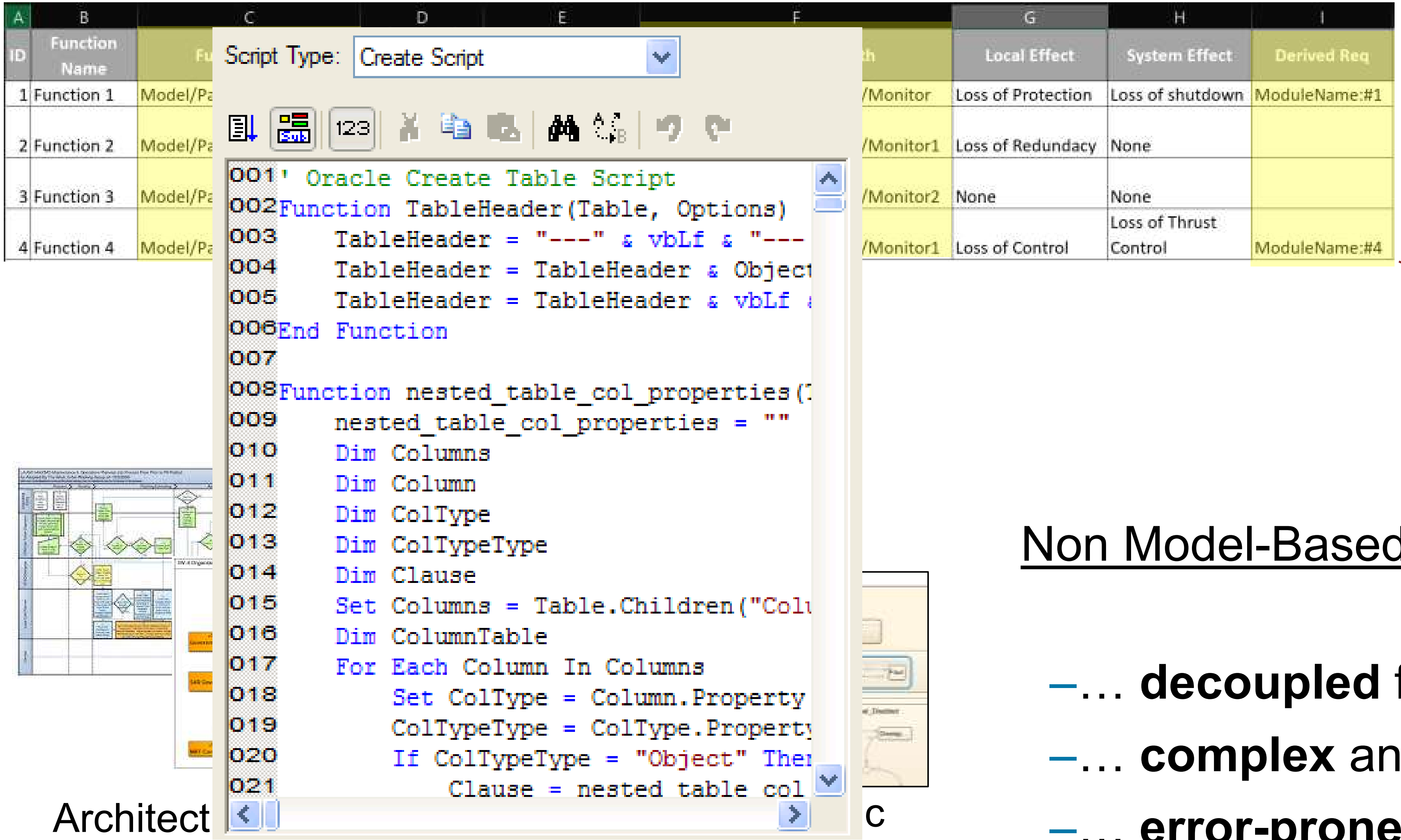
Aero Standards

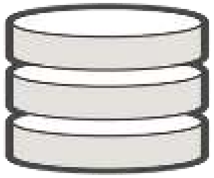


ISO 26262

Auto Standards

How Safety Analysis Is Done Today

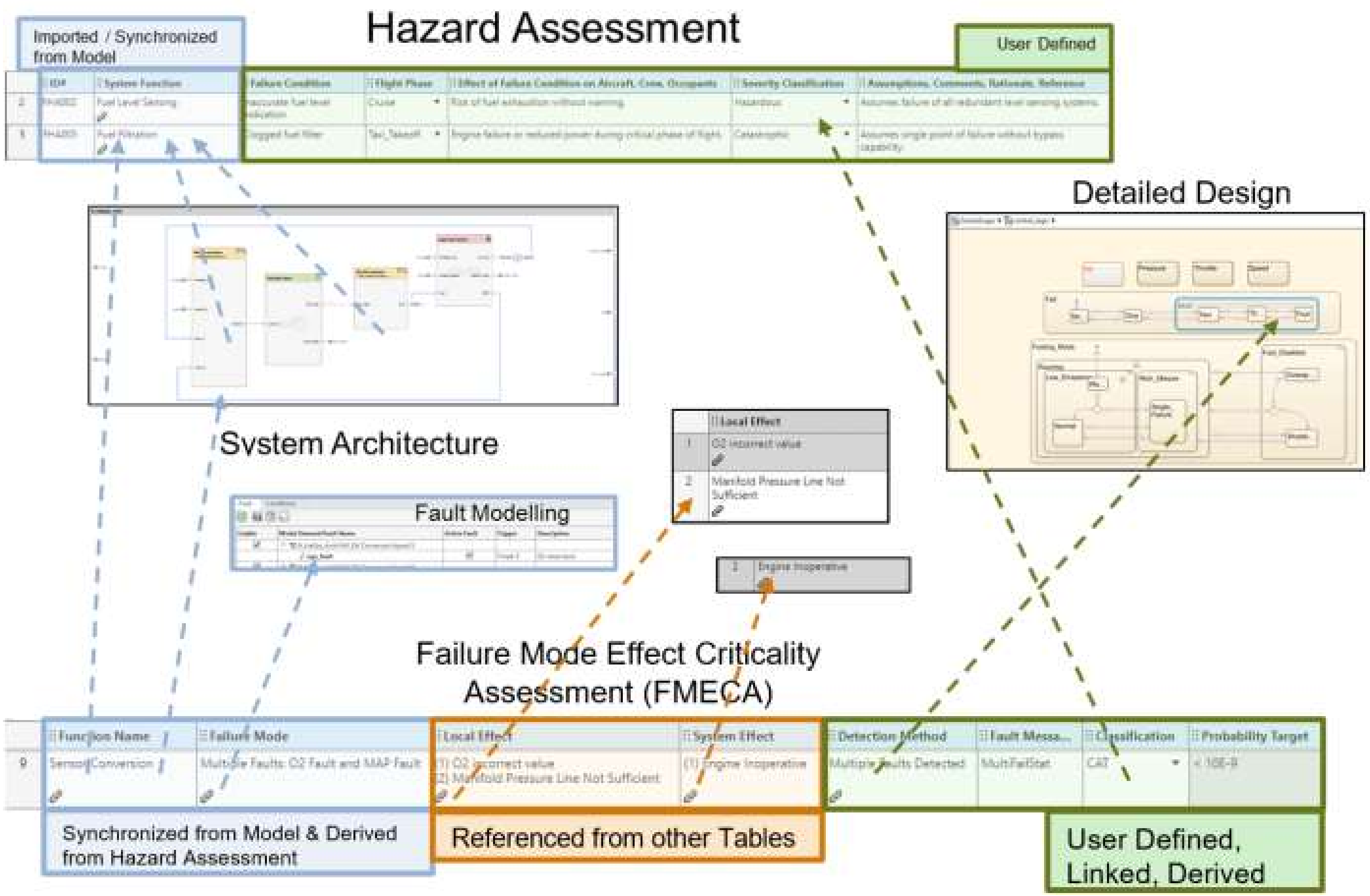




<u>Non Model-Based Safety Analysis is</u> …

– … **decoupled** from design work
– … **complex** and **complicated**
– … **error-prone**

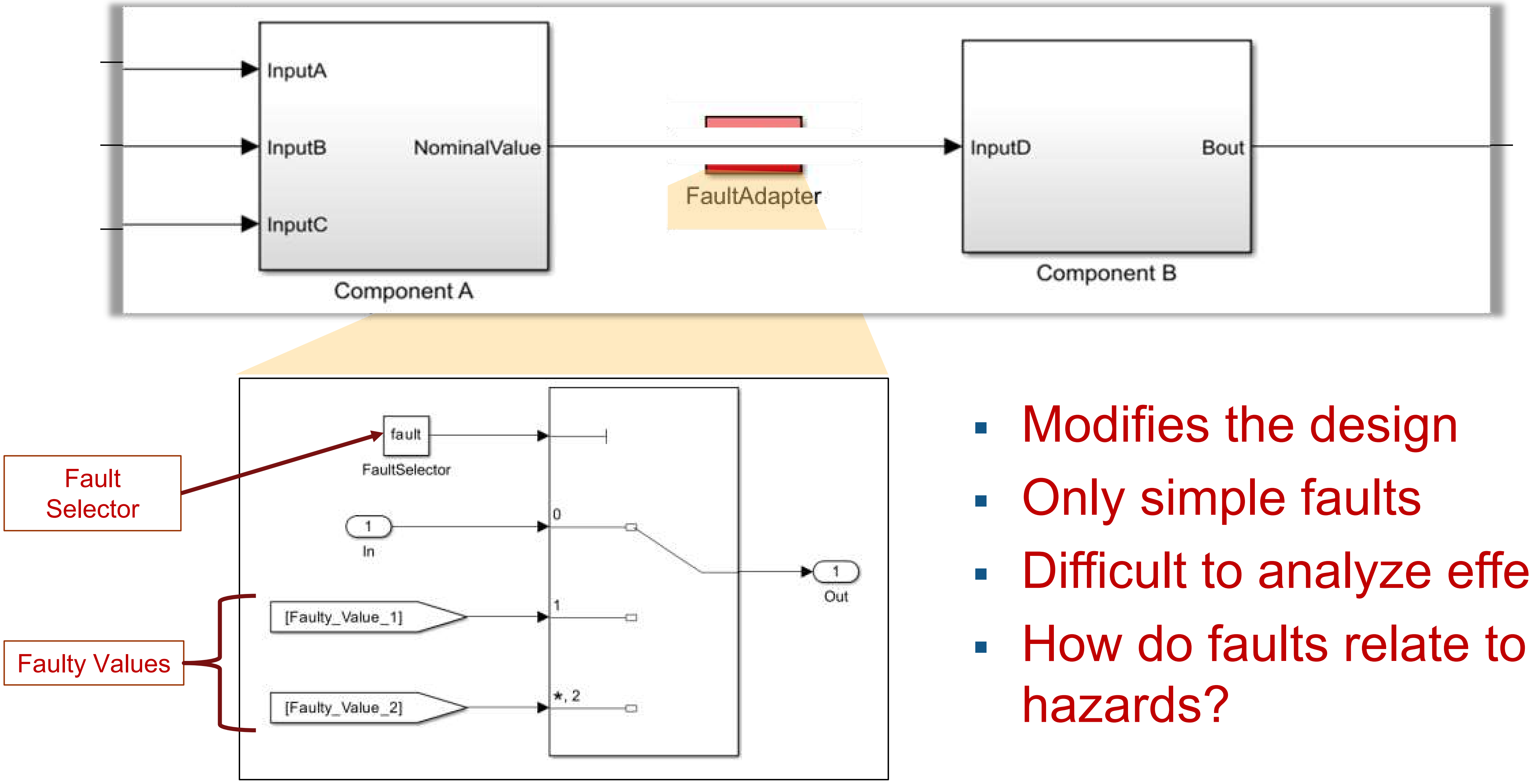
Why Model-Based Safety Analysis is the way to go



Model-Based Safety Analysis is …

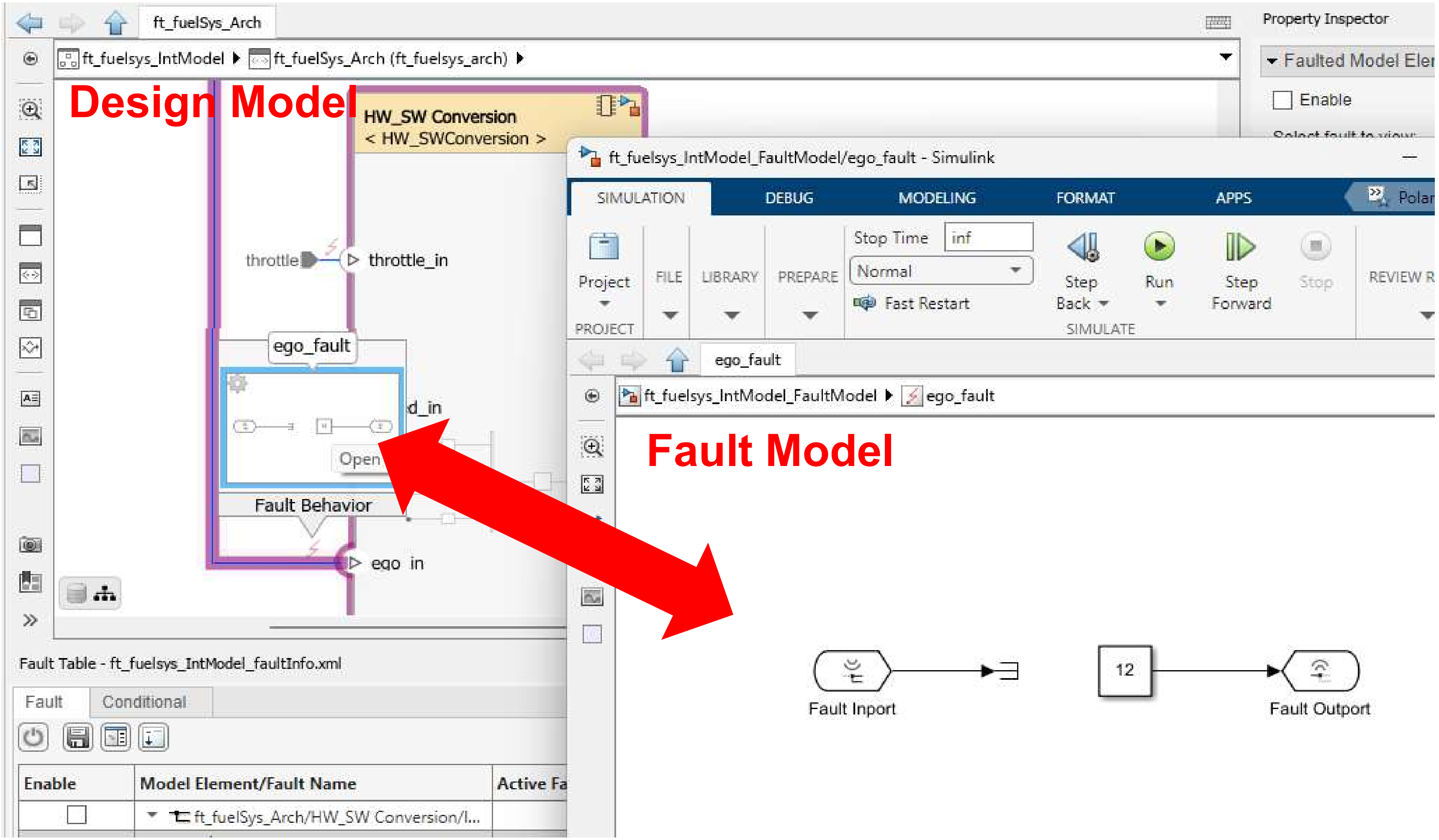
- … **fully integrated** with design
- … **fully traceable** (changes etc.)
- … **consistent** & **validated**
- Synergy: fault modeling, FTA, tests

How is fault injection done today

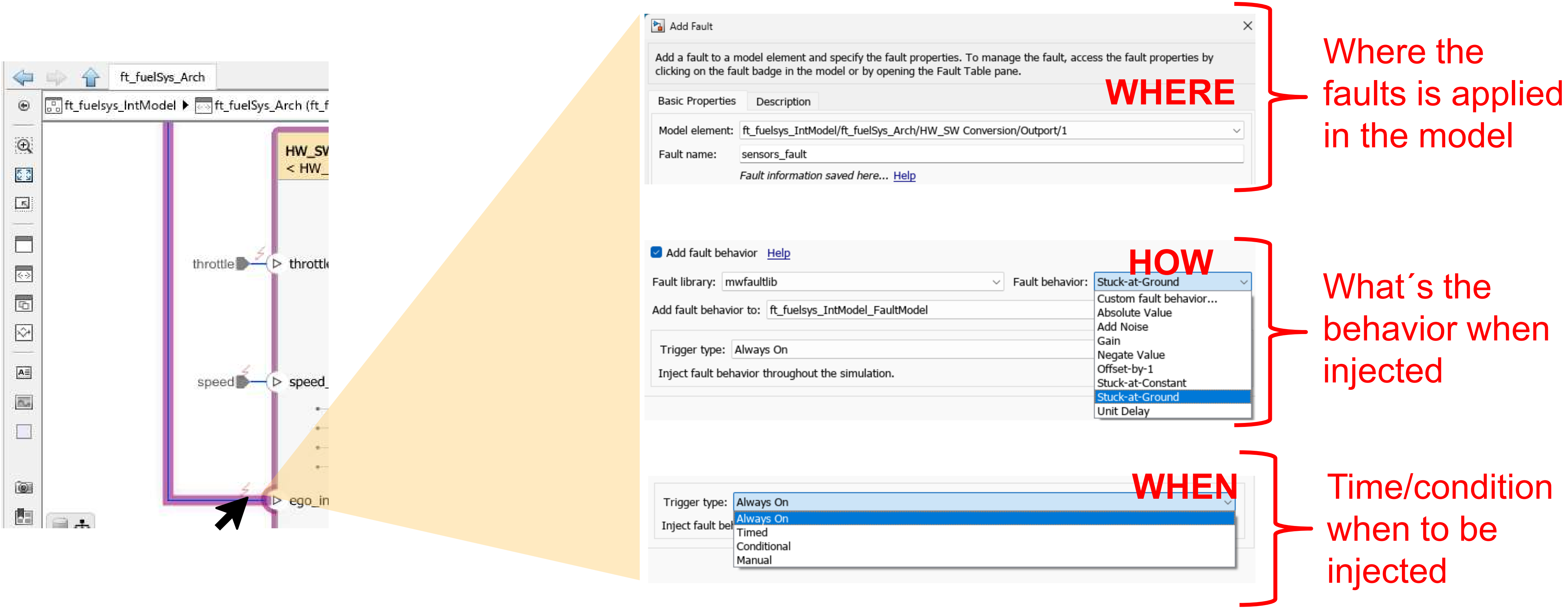


- Modifies the design
- Only simple faults
- Difficult to analyze effects
- How do faults relate to hazards?

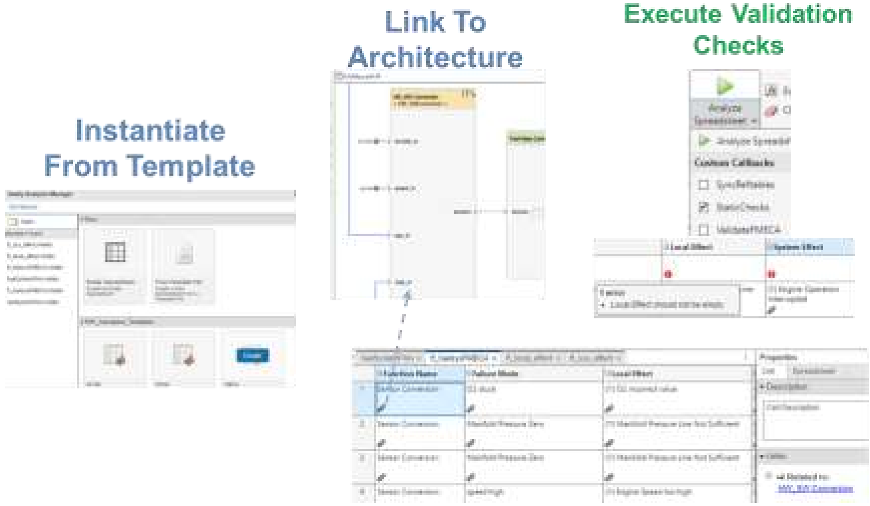
Model faults without modifying Design



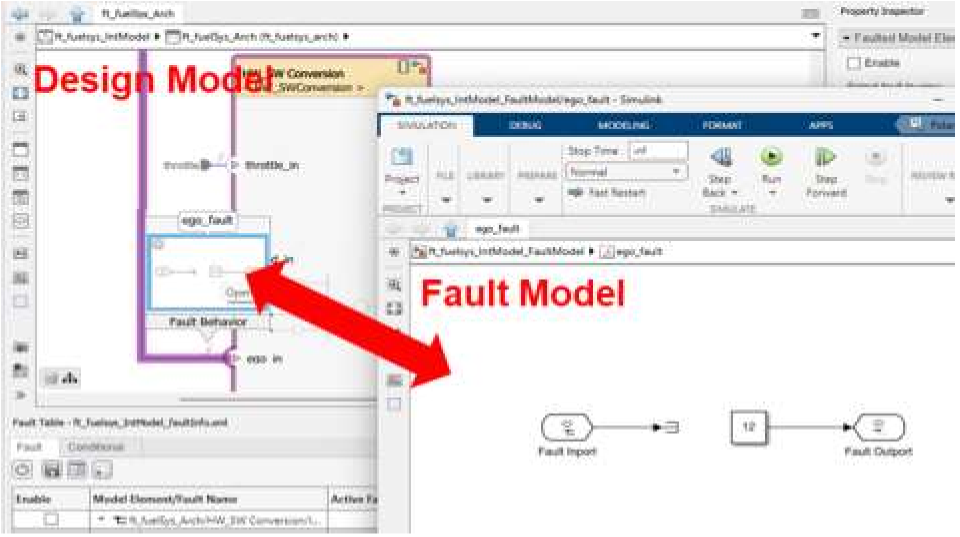
Model faults without modifying Design



Recap – Fault Analyzer Capabilities

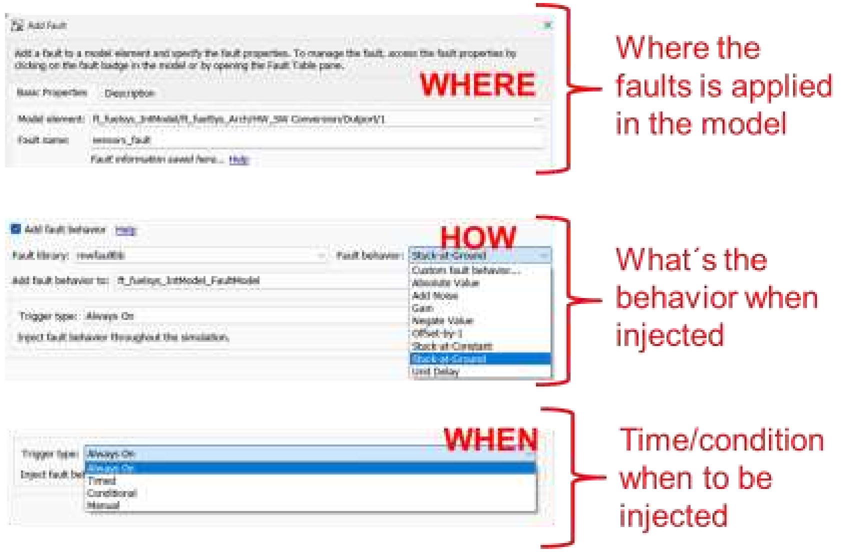


Capture Analysis, Link to Architecture & Perform Validation Checks

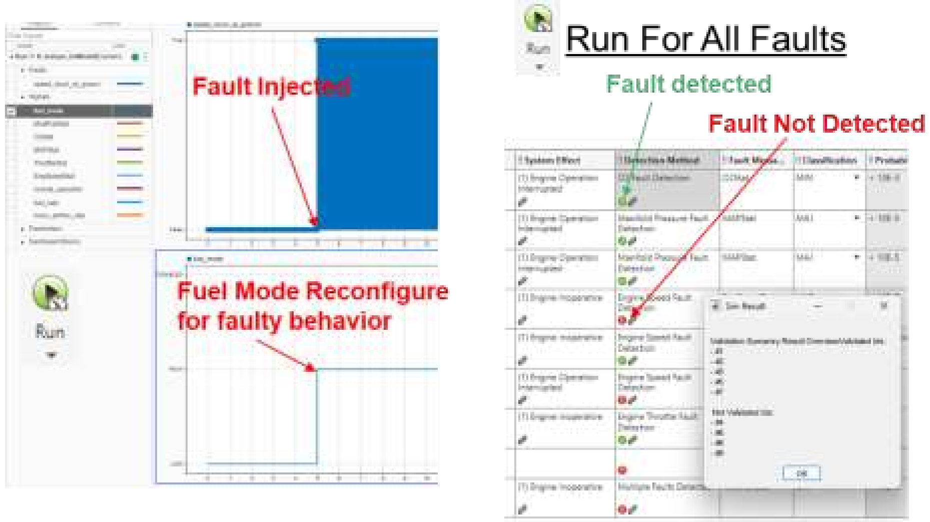


Model Faults Without Modifying Design

Simulink Fault Analyzer™

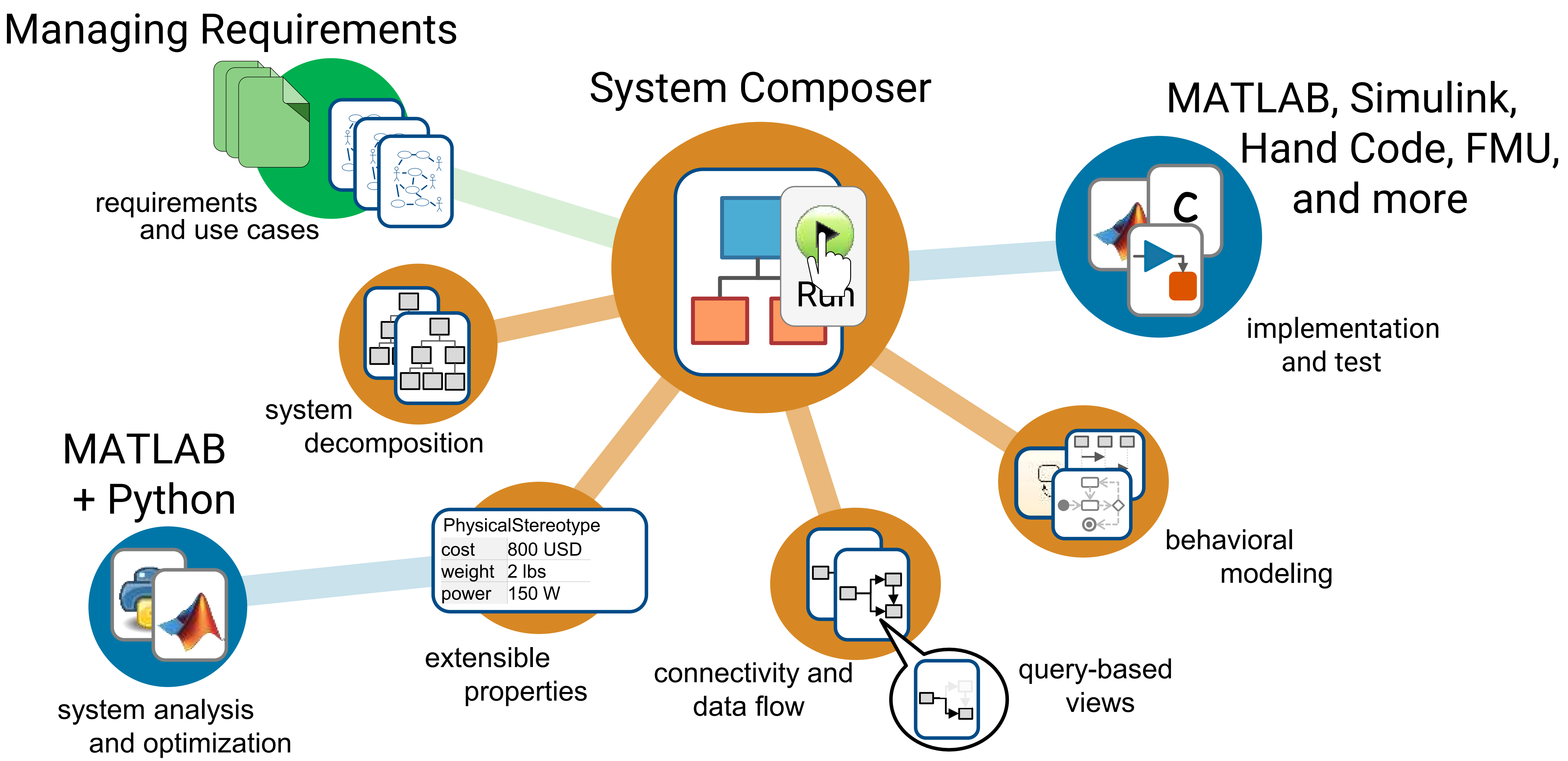


Characterize Faults Behavior

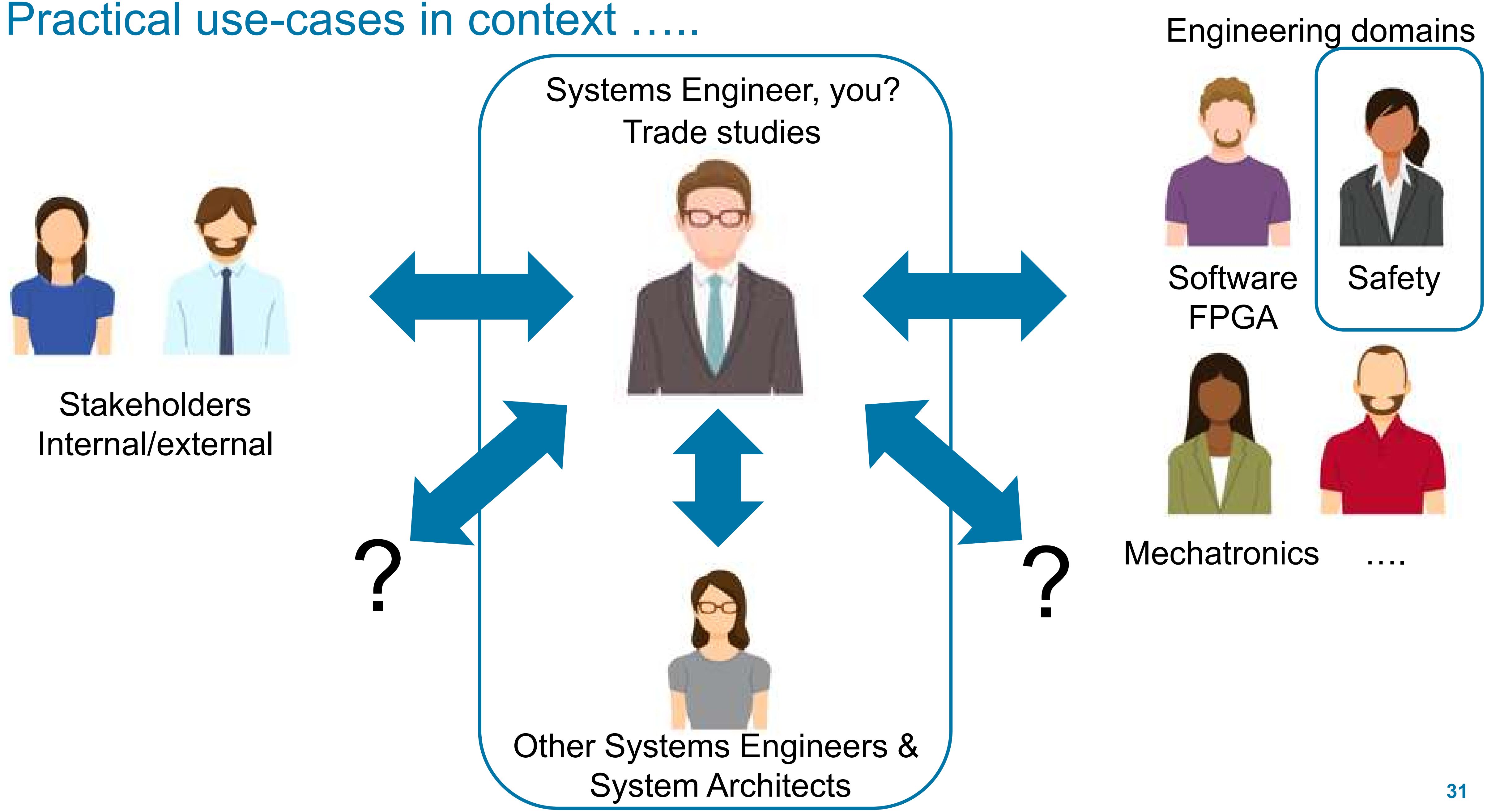


Use Simulation to Validate Safety Analysis

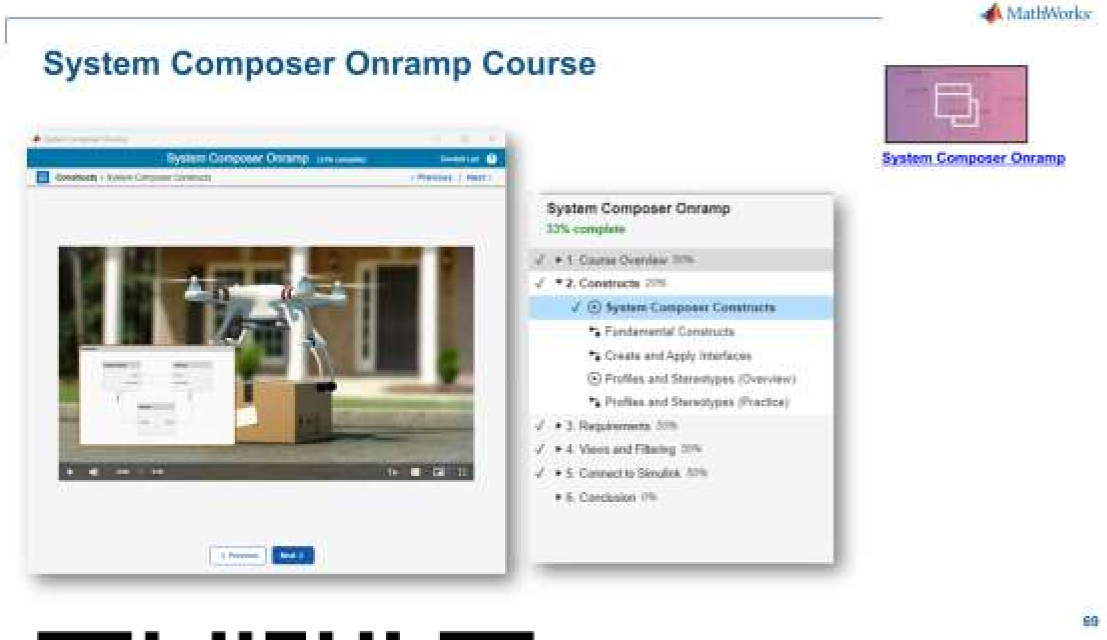
Model-Based Systems Engineering at MathWorks



Practical use-cases in context …..



Summary



Scan me for digital handouts