

Module SEFS Architecting

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Abstract

Understanding the context is essential to understand the problem and the solution space. We discuss the way companies work, the customer, business, and life cycle contexts, and how to scope the work.

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SEFS Architecting Fundamentals

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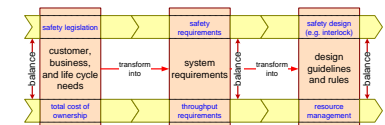
Abstract

Architecting transforms the needs and understanding of the current situation into a system specification and high-level design. The architecture description captures the overview, the rationale, and provides guidance and rules for the design.

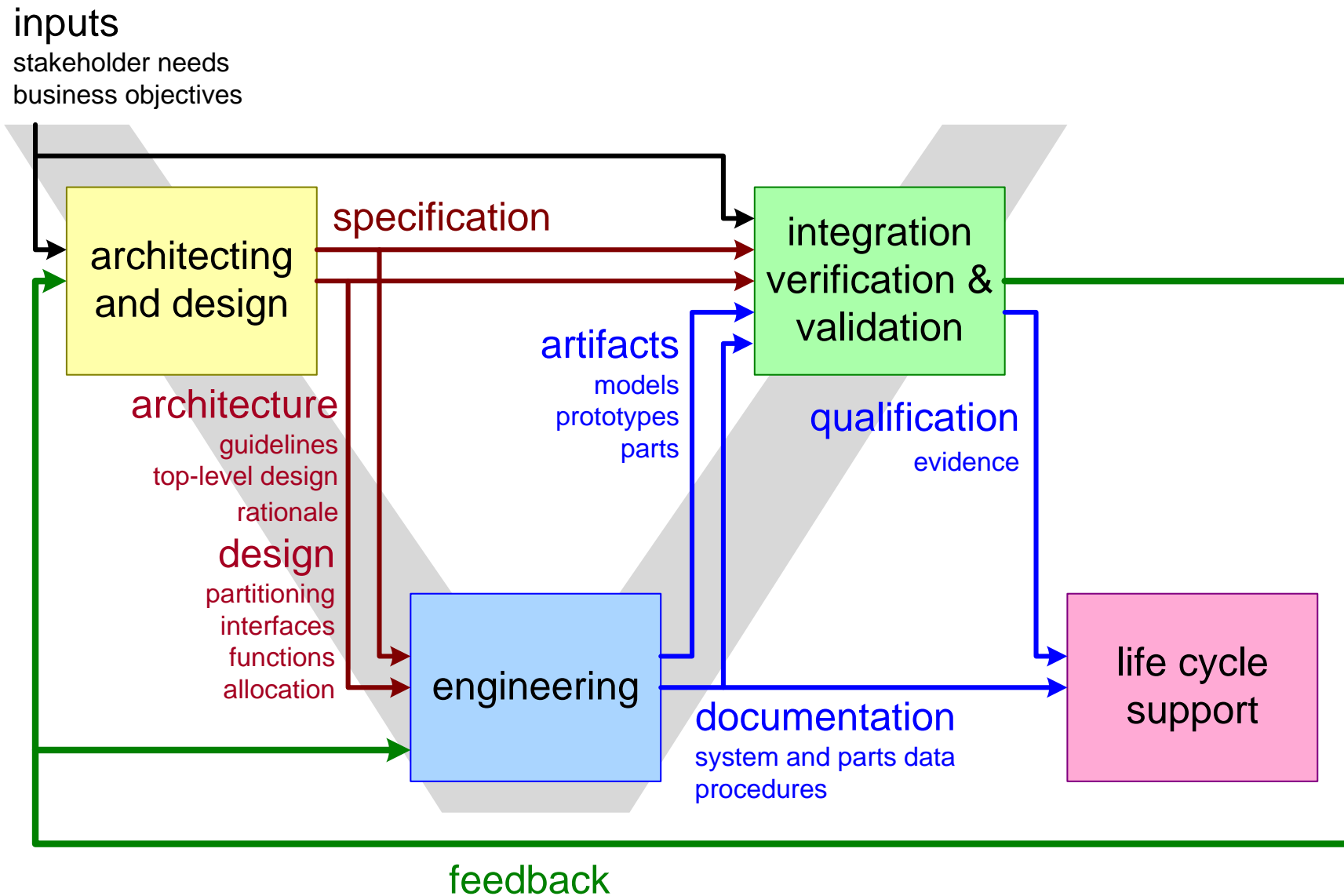
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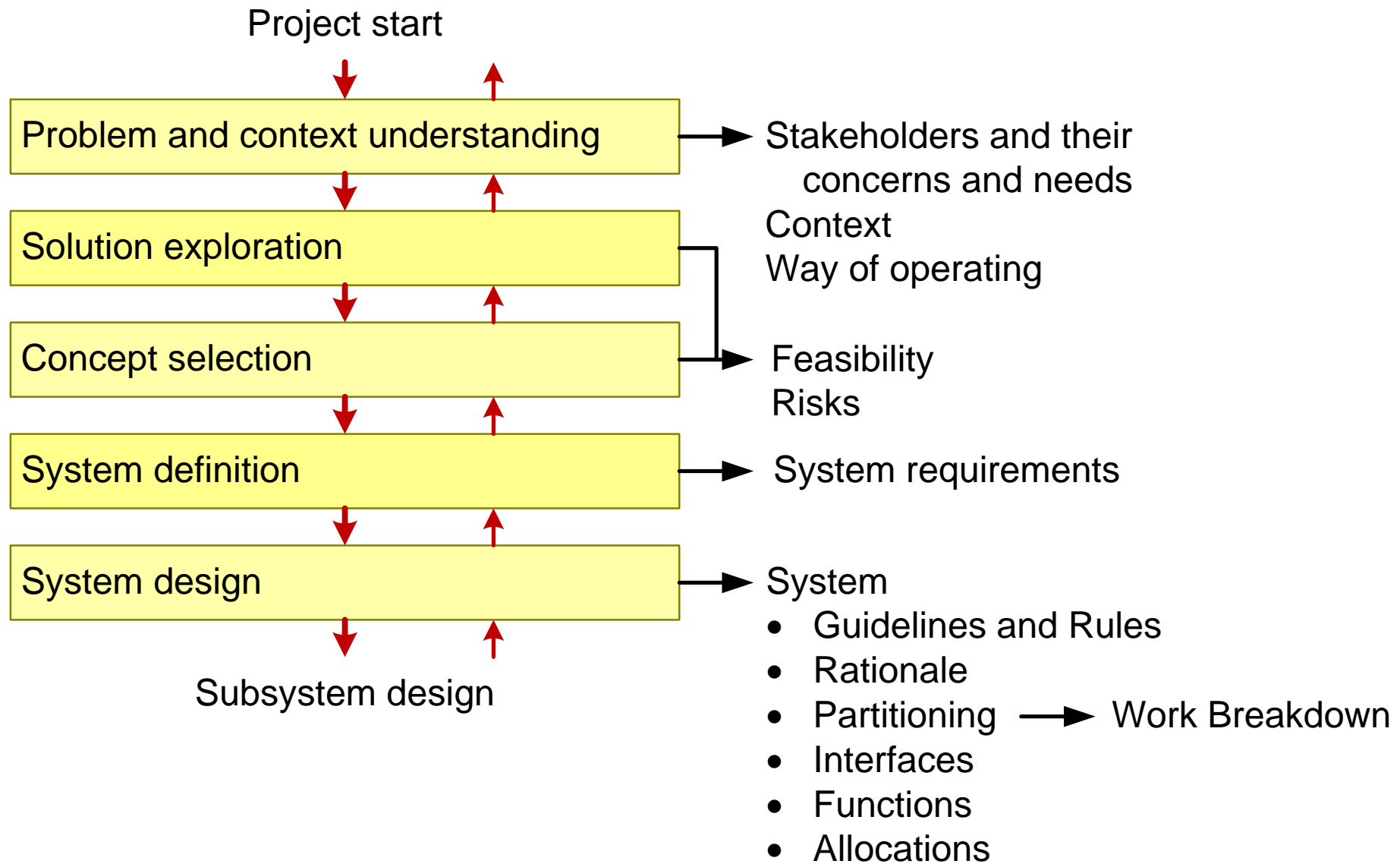
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Architecting and Design in the V-model



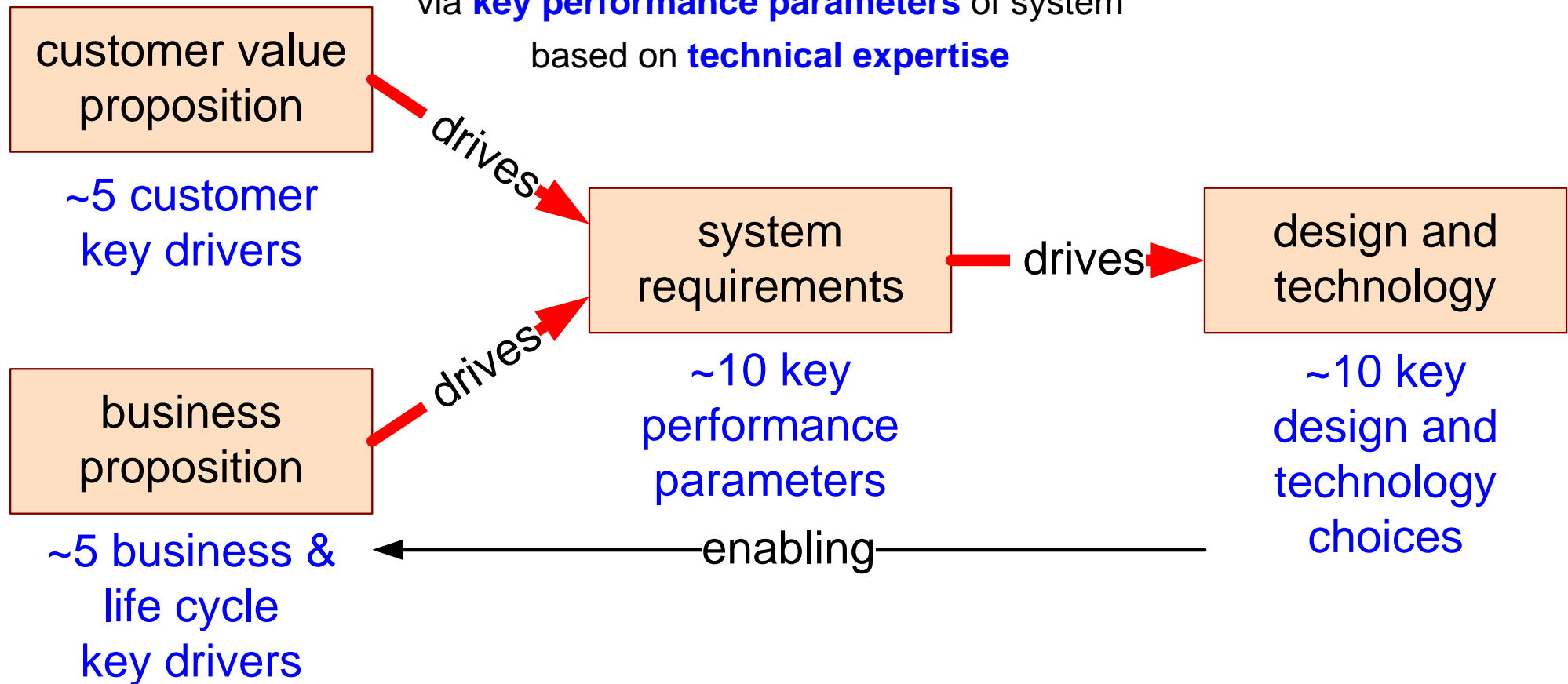
Architecting Workflow



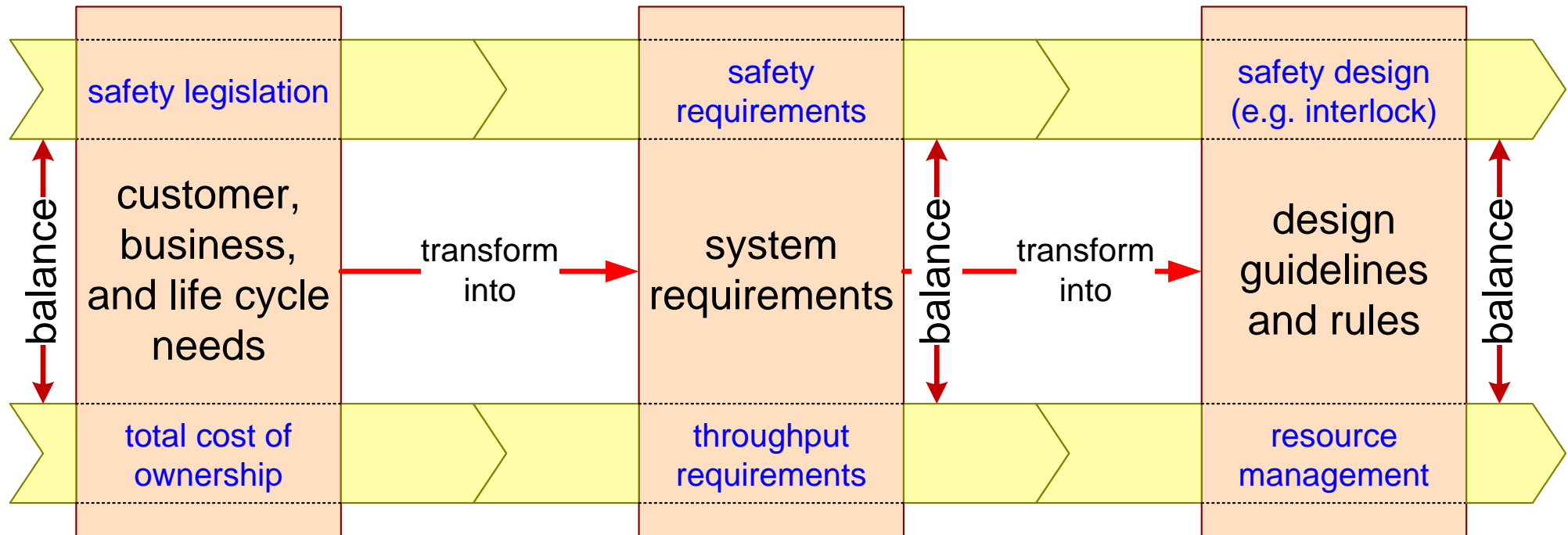
The Architecture Captures the Rationale

Systems Engineering: *Fitness-For-Purpose*

Achieving **customer** and **business key drivers**
via **key performance parameters** of system
based on **technical expertise**



Architecture Provides Guidelines and Rules



SEFS Concept Selection

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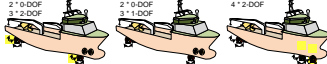
Abstract

Concept selection is useful at many levels, from the customer application to the technology concept for specific functions. The Pugh matrix is a lightweight decision matrix facilitating early phase concept selections. When the design is crystallizing out, then trade-off analysis provides a more specific insight in the relation between specification and design parameters.

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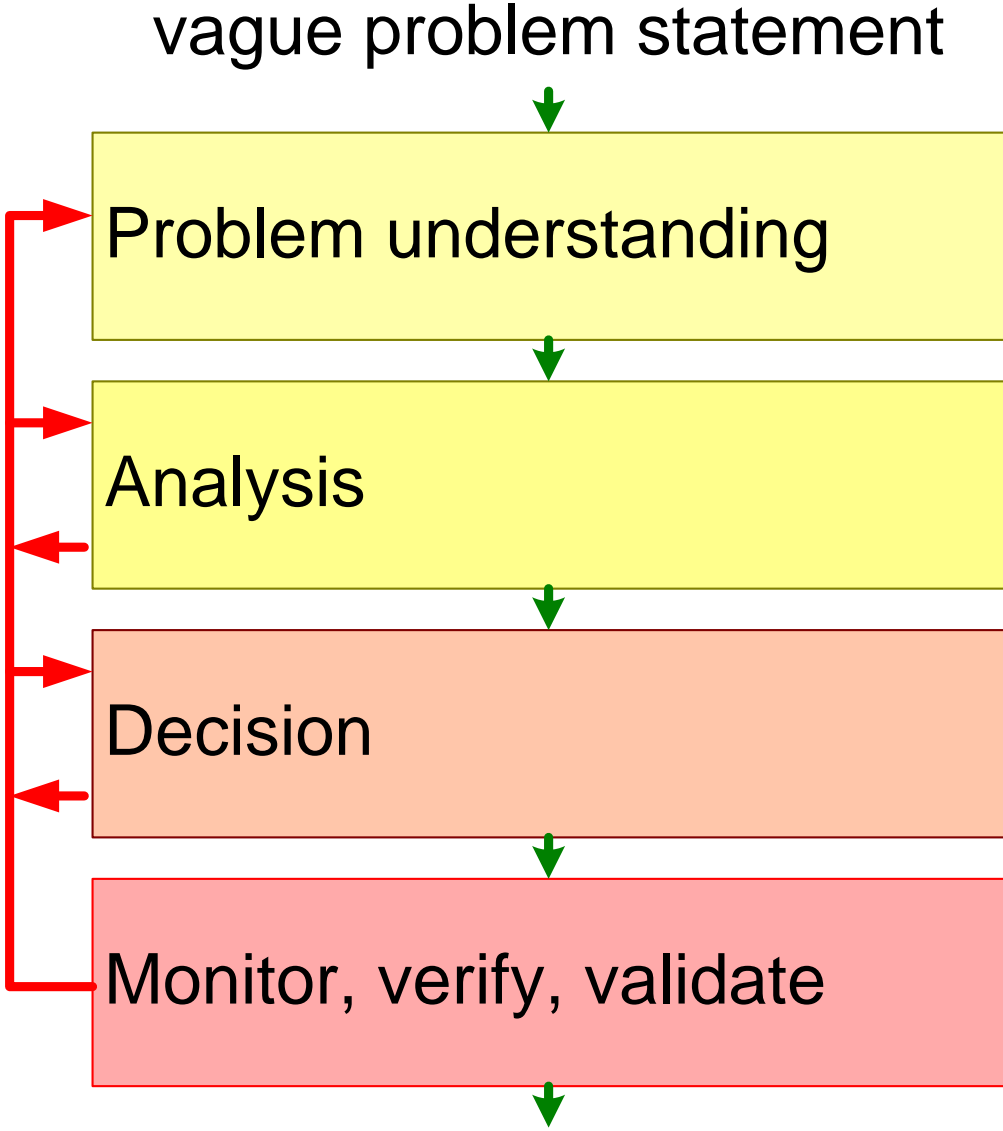
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| | | | |
|--------------------|---|---|---|
| Manoeuvrability | 4 | 4 | 5 |
| Energy consumption | 5 | 3 | 5 |
| Development Cost | 3 | 4 | 2 |
| Maturity (risk) | 3 | 4 | 1 |
| Purchasing Cost | 3 | 4 | 3 |
| Maintenance Cost | 2 | 4 | 2 |

Exploration and Analysis Flow of Concepts



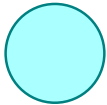
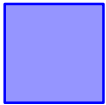
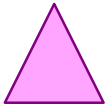






Pugh Matrix: a Light-Weight Decision Matrix

Define at least 3 concepts

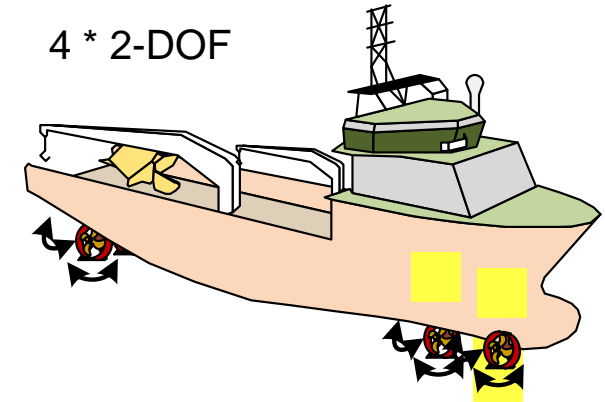
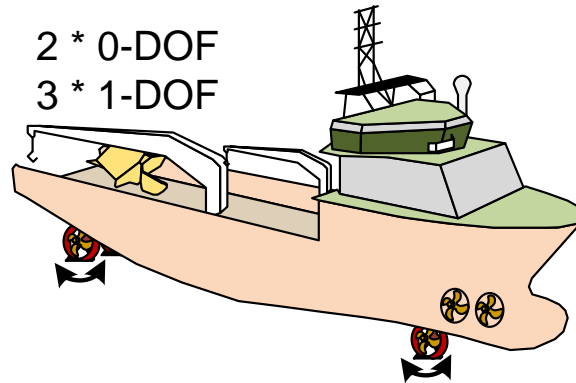
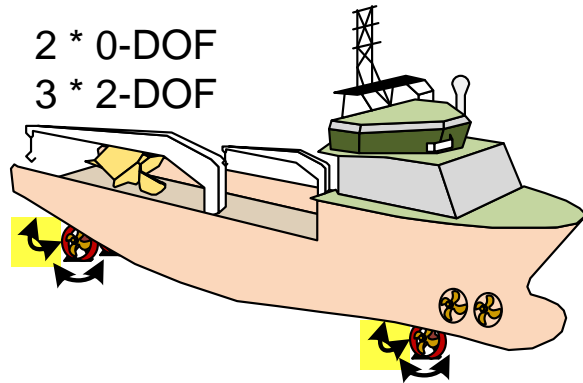
Define 7 to 10 criteria for selection

Score the concepts against the criteria, for example using a scale from 1 to 5: 1 = very poor, 5 = very good

Recommend a concept with a rationale

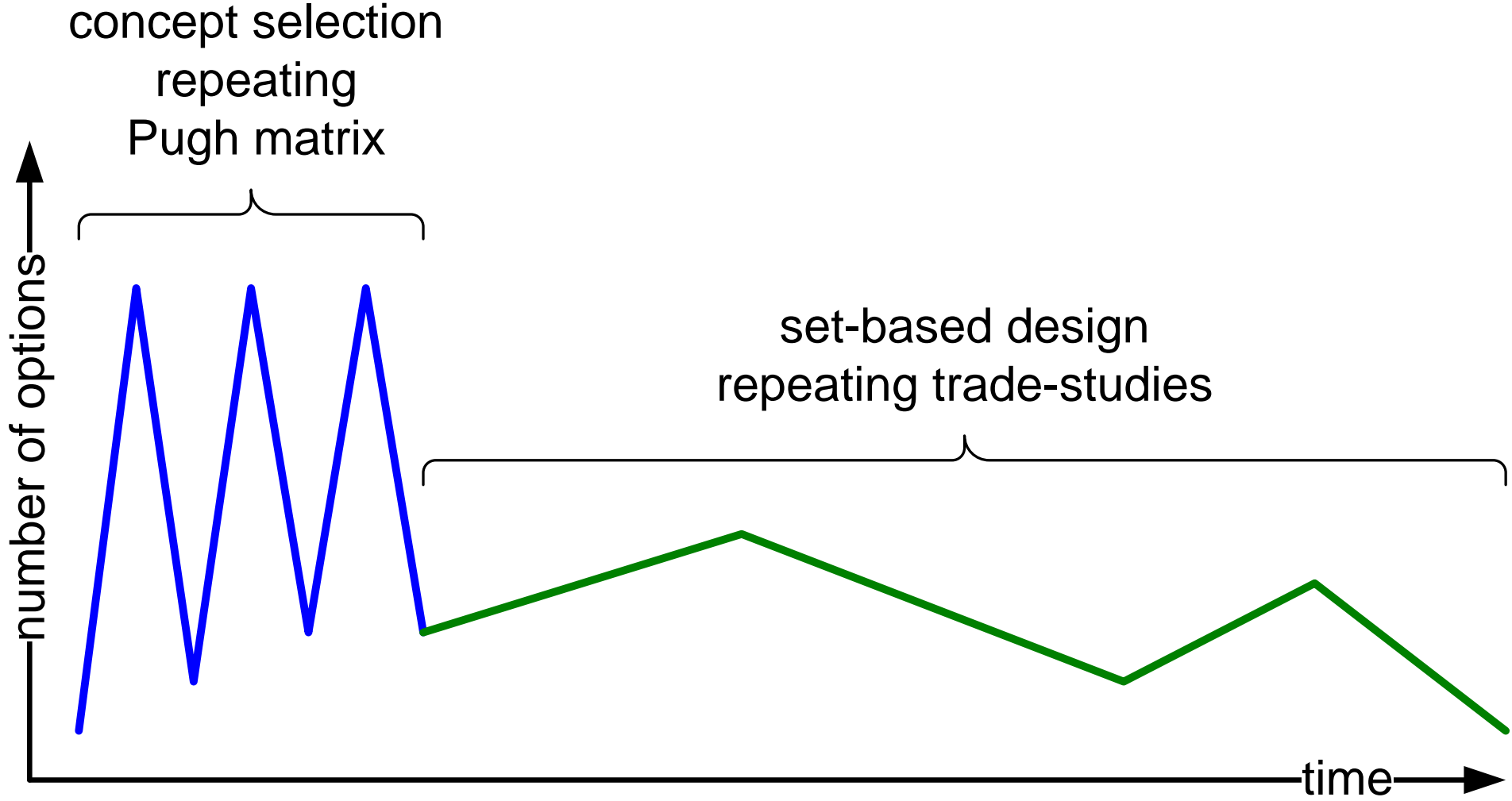
| | concept 1  | concept 2  | concept 3  |
|-------------|--|--|--|
| criterion 1 |  |  |  |
| | | | |
| criterion n |  |  |  |
| | | | recommended, because ... |

Example of Pugh Matrix

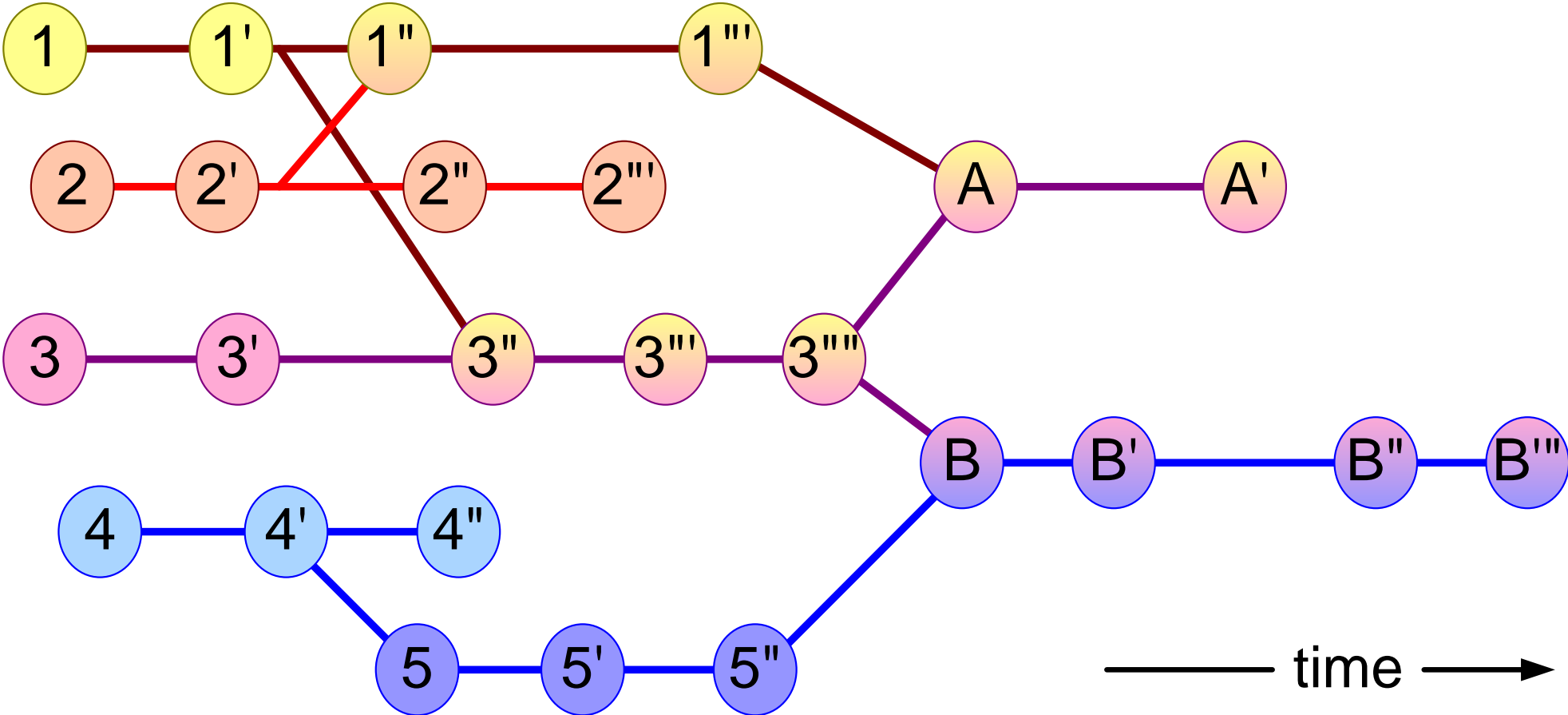


| | | | |
|--------------------|---|---|---|
| Manoeuvrability | 4 | 4 | 5 |
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| Maintenance Cost | 2 | 4 | 2 |

Repeated Divergence and Convergence



Set-based Design



SEFS Dynamic Behavior

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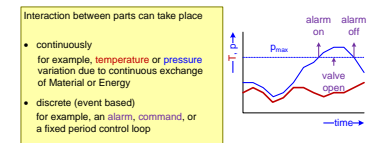
Abstract

The desired system behavior and performance emerges from the interaction of the parts. The challenge in architecting is capturing the relevant dynamic behavior to facilitate reasoning about system behavior and performance.

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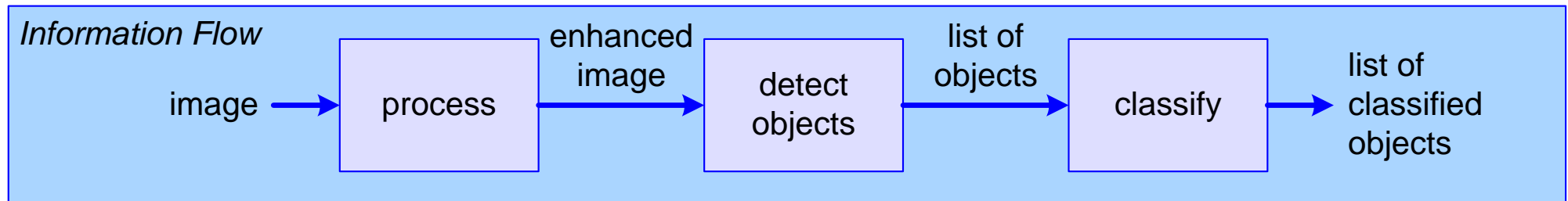
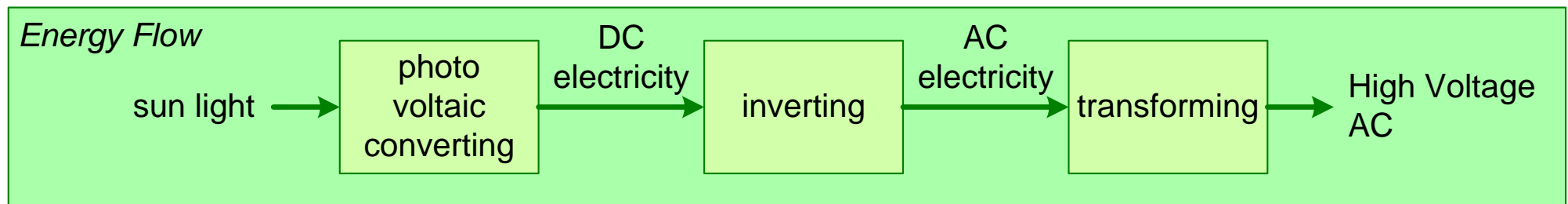
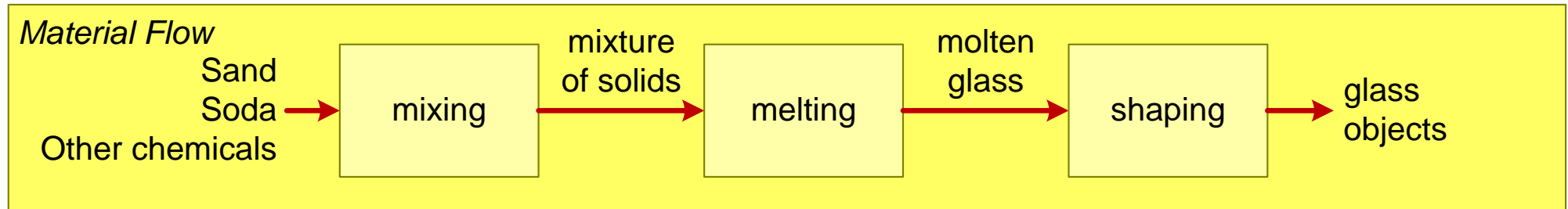
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Interaction between parts takes place via exchange of

- **M**aterial
- **E**nergy
- **I**nformation

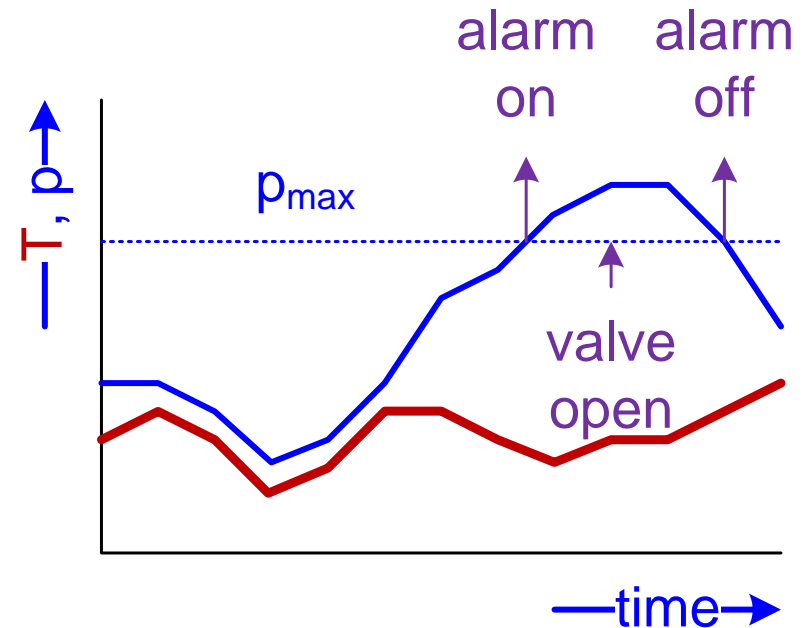
Simple Examples of MEI Flows



Dynamic Behavior and Time

Interaction between parts can take place

- continuously
for example, **temperature** or **pressure** variation due to continuous exchange of Material or Energy
- discrete (event based)
for example, an **alarm**, **command**, or a fixed period control loop



Simple Examples of Dynamic Behavior

Every second:

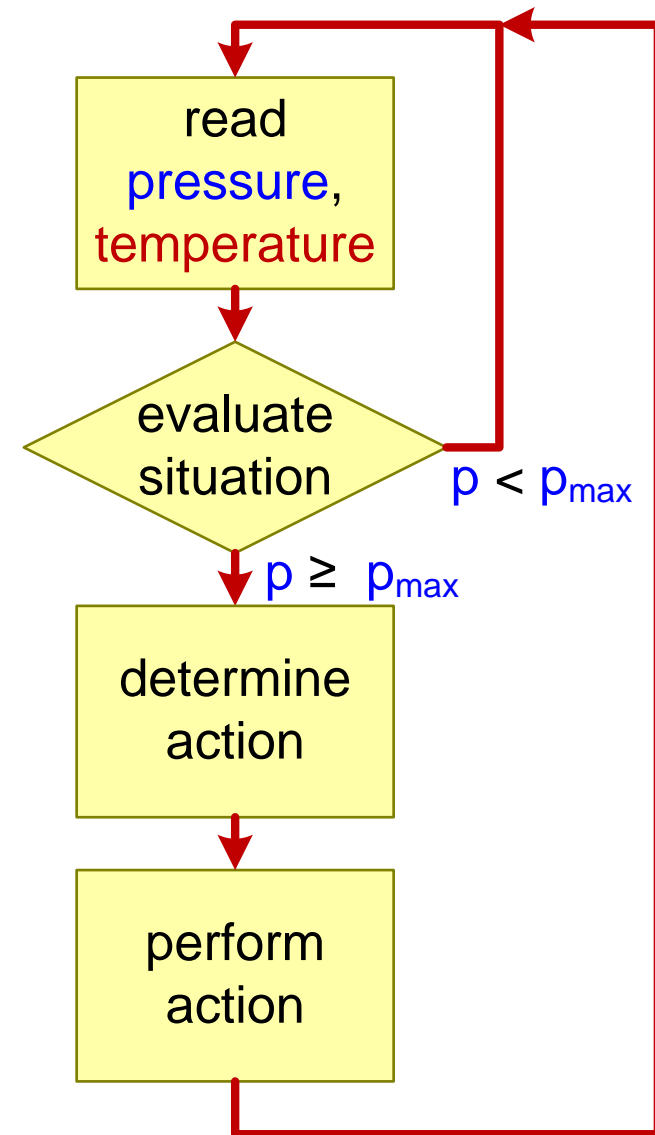
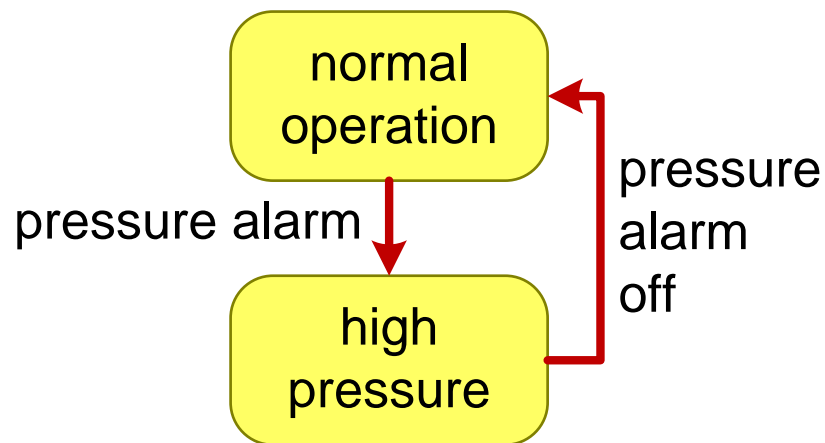
read **pressure**, **temperature**

evaluate situation (e.g., $p < p_{max}$)

determine action

(e.g., lower pressure by opening valve)

perform action (e.g. **open valve**)



SEFS Modeling

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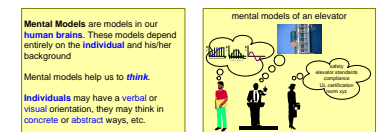
Abstract

In systems engineering we use many kinds of models. We use simulations for analysis, capture system structure information in MSBE models, and create conceptual models for understanding, communication, reasoning, and supporting decision making.

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First Principle Models

First principle model: a model based on **theoretical** principles.

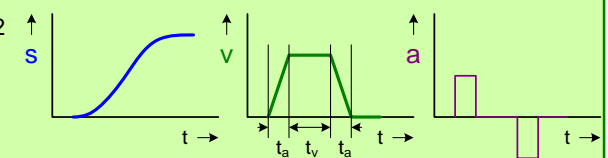
A first principle model **explains** the desired property from first principles from the **laws of physics**.

A first principle model **requires values** for **incoming parameters** to calculate results.

first principle model $t_{\text{top floor}}$ elevator

$$v = \frac{dS}{dt} \quad a = \frac{dv}{dt} \quad j = \frac{da}{dt}$$

Position in case of uniform acceleration:

$$S_t = S_0 + v_0 t + \frac{1}{2} a_0 t^2$$


$$t_{\text{top floor}} = t_a + t_v + t_a$$

$$t_a = v_{\text{max}} / a_{\text{max}}$$

$$S(t_a) = \frac{1}{2} * a_{\text{max}} * t_a^2$$

$$S_{\text{linear}} = S_{\text{top floor}} - 2 * S(t_a)$$

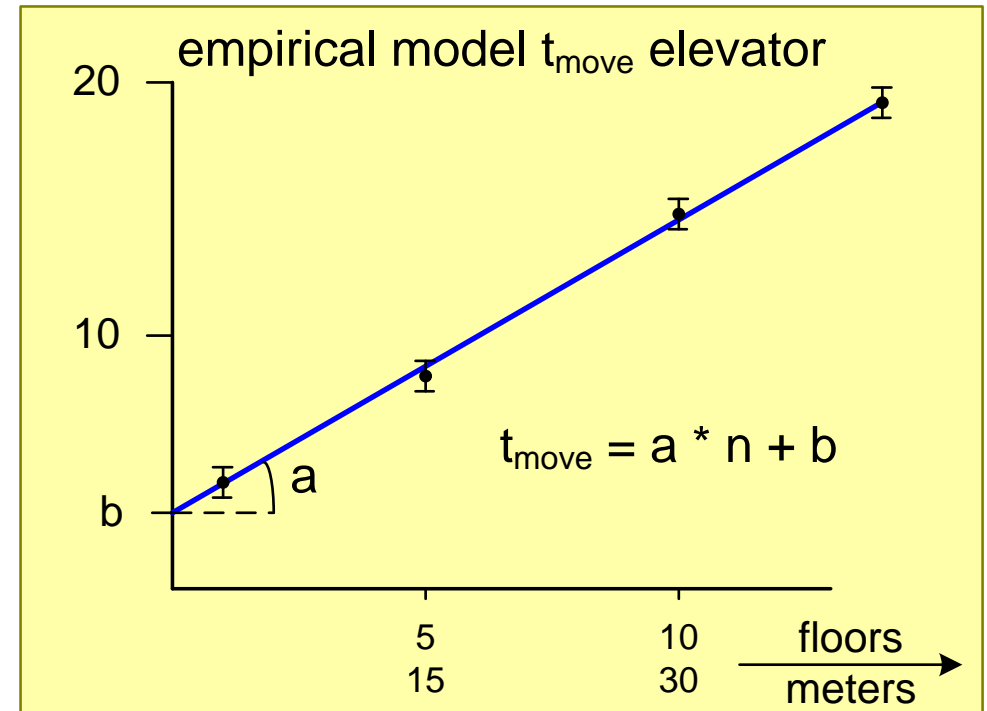
$$t_v = S_{\text{linear}} / v_{\text{max}}$$

Empirical Models

Empirical model: a model based on **observations** and **measurements**.

An empirical model **describes** the observations.

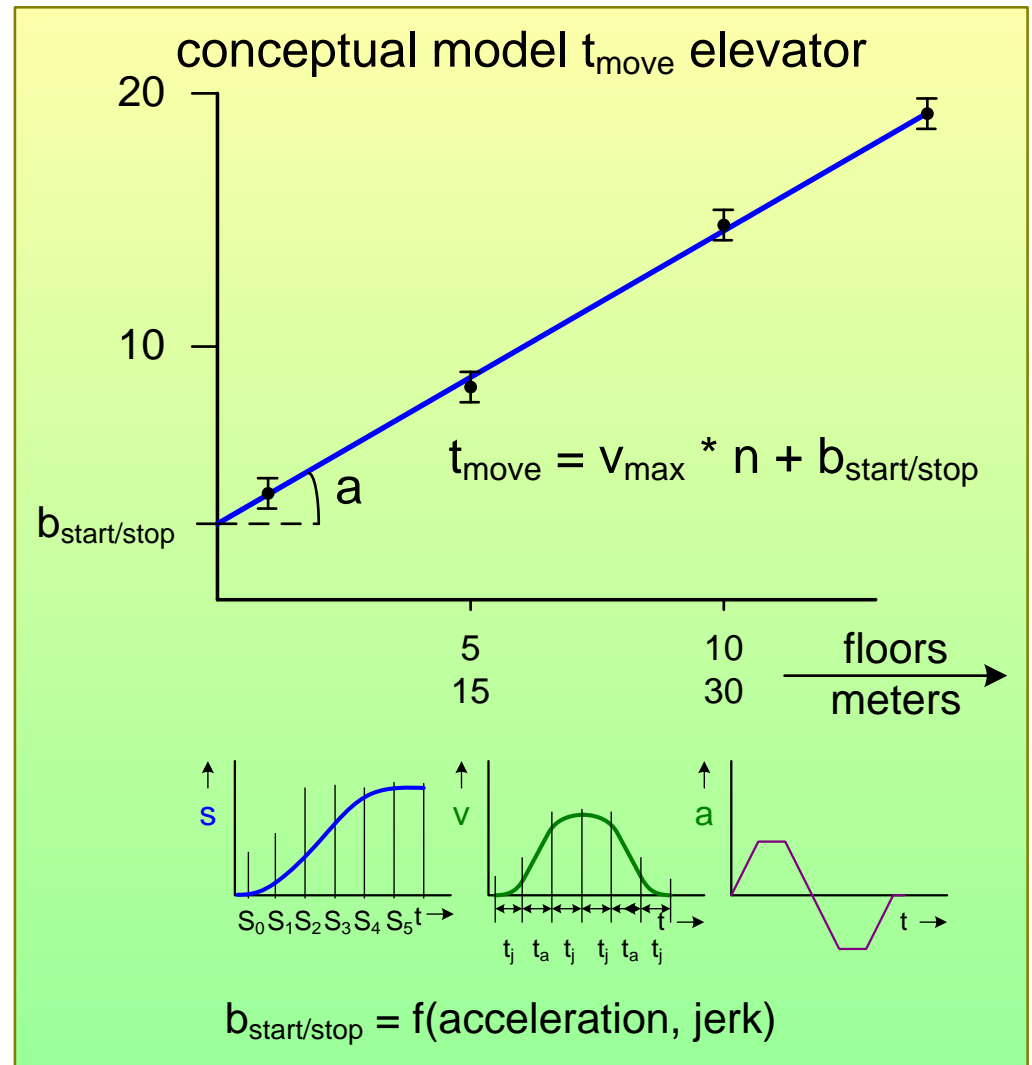
An empirical model provides **no understanding**.



Conceptual Models

Conceptual model: a model **explaining observations** and **measurements** using a selection of **first principles**.

A conceptual model is a **hybrid** of empirical and first principle models; **simple** enough to **understand** and to **reason, realistic** enough to make **sense**.

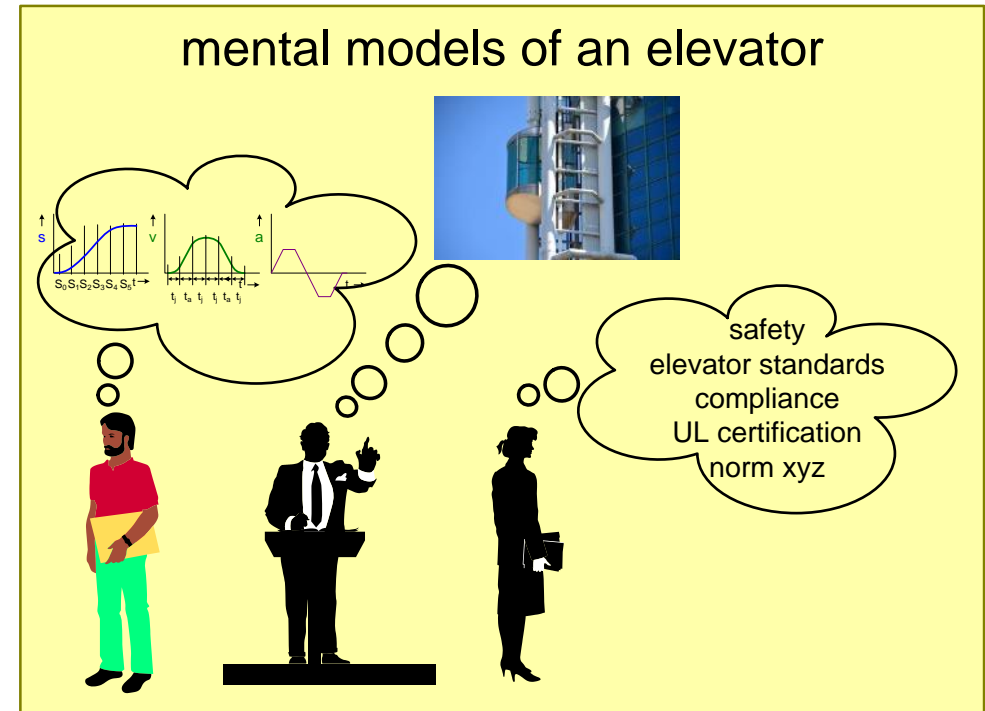


Mental Models

Mental Models are models in our **human brains**. These models depend entirely on the **individual** and his/her background

Mental models help us to **think**.

Individuals may have a **verbal** or **visual** orientation, they may think in **concrete** or **abstract** ways, etc.



Simulations

Simulation: an executable model based on **first principle** and **empirical models**.

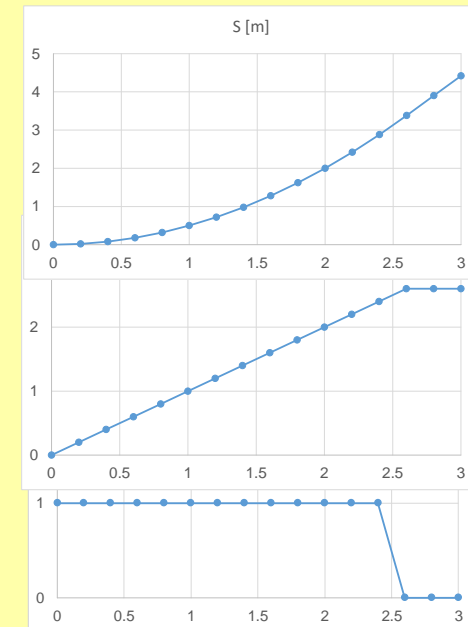
Designers run simulations to **explore**, **analyze**, and **gain insights**.

A simulation provides **understanding**, when **the users transform** the outcomes into **insights**.

simulation of an elevator

| | |
|------|--------------------|
| dt | 0.2 s |
| vmax | 2.5 m/s |
| amax | 1 m/s ² |

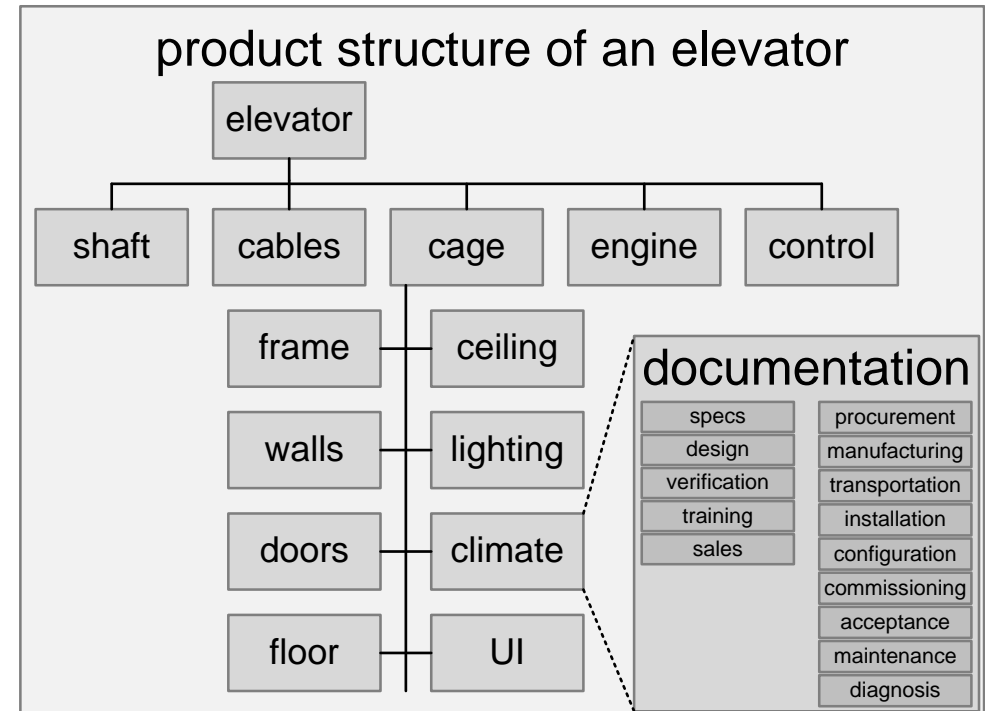
| t (s) | s (m) | v (m/s) | a (m/s ²) |
|-------|-------|---------|-----------------------|
| 0 | 0 | 0 | 1 |
| 0.2 | 0.02 | 0.2 | 1 |
| 0.4 | 0.08 | 0.4 | 1 |
| 0.6 | 0.18 | 0.6 | 1 |
| 0.8 | 0.32 | 0.8 | 1 |
| 1 | 0.50 | 1 | 1 |
| 1.2 | 0.72 | 1.2 | 1 |
| 1.4 | 0.98 | 1.4 | 1 |
| 1.6 | 1.28 | 1.6 | 1 |
| 1.8 | 1.62 | 1.8 | 1 |
| 2 | 2.00 | 2 | 1 |
| 2.2 | 2.42 | 2.2 | 1 |
| 2.4 | 2.88 | 2.4 | 1 |
| 2.6 | 3.38 | 2.6 | 0 |
| 2.8 | 3.90 | 2.6 | 0 |
| 3 | 4.42 | 2.6 | 0 |
| 3.2 | 4.94 | 2.6 | 0 |
| 3.4 | 5.46 | 2.6 | 0 |



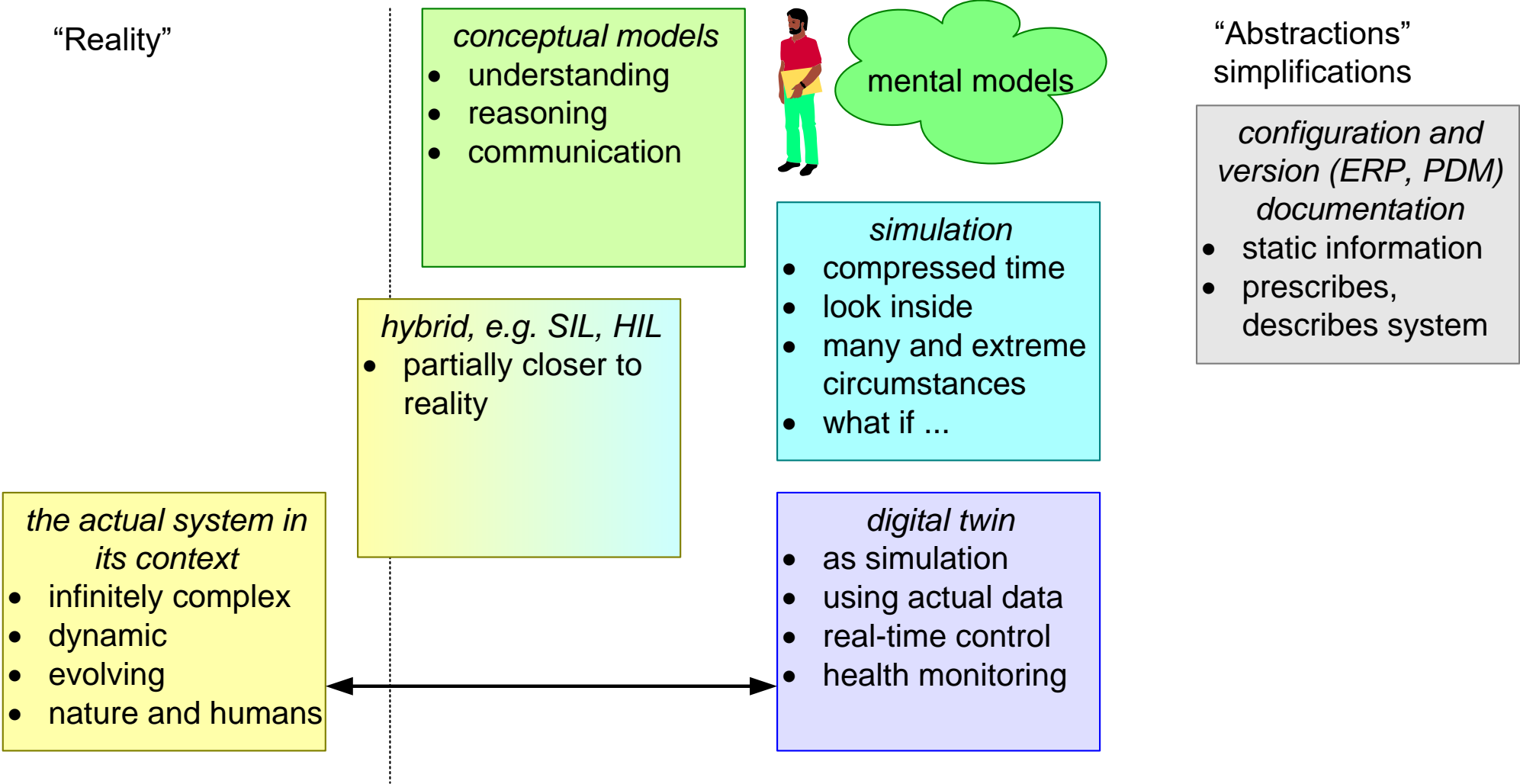
Product Structure and Documentation

The **Product Structure** prescribes the **parts hierarchy**. Each part in the hierarchy has associated **documentation** and **information** for the entire **life cycle**.

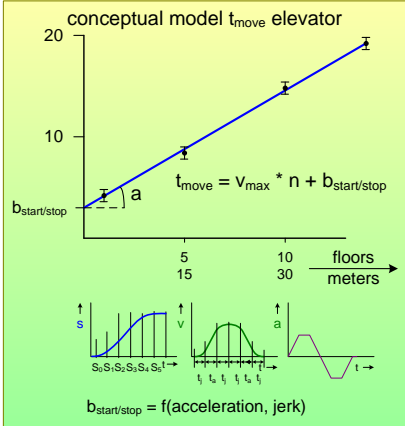
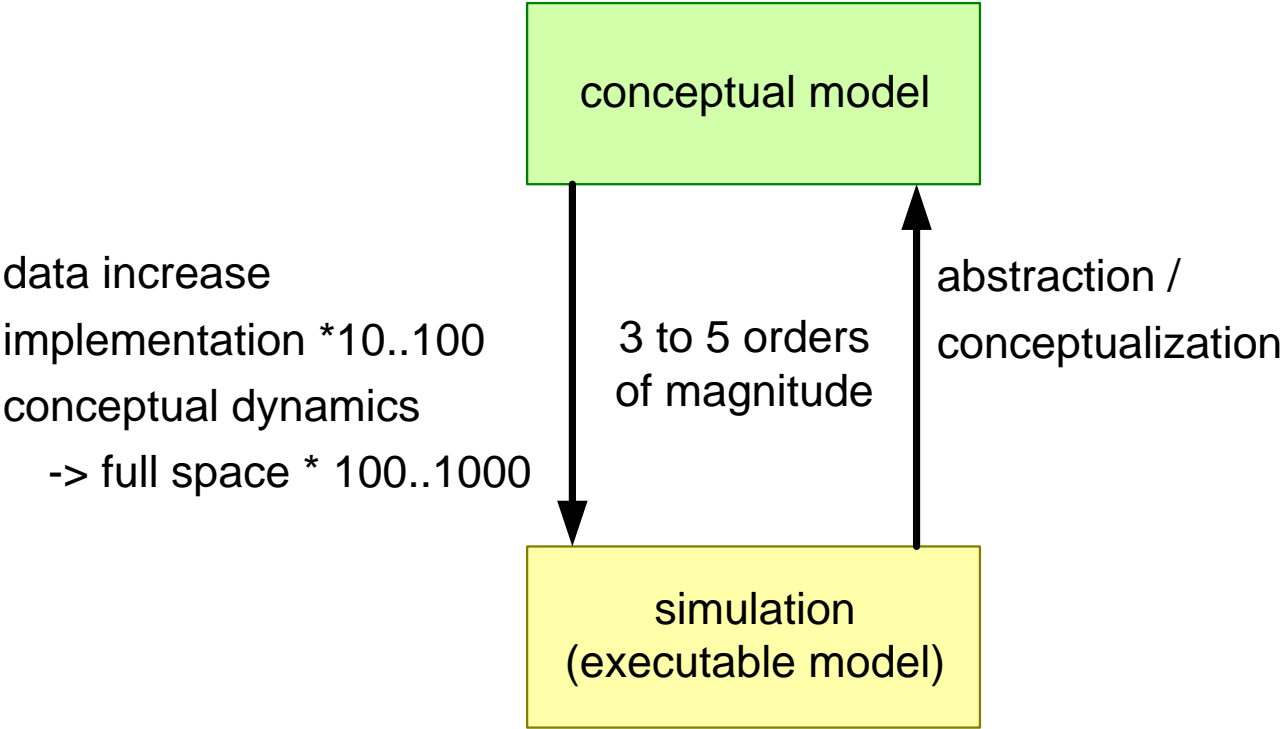
The Product Structure and associated documentation help the organization to **manage** all processes from creation to decommissioning and recycling, via **ERP, PDM, PLM** etc. systems.



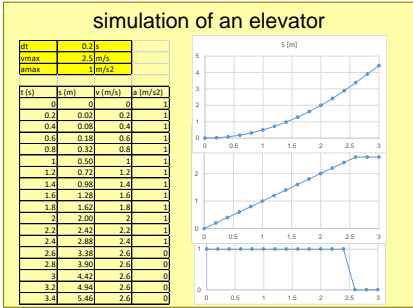
Map of Various Model Types



Conceptualization Reduces 3 to 5 Orders of Magnitude



S, a, v, j
 t_{floor} , t_v , t_a



Conceptual Models are at All Levels

