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

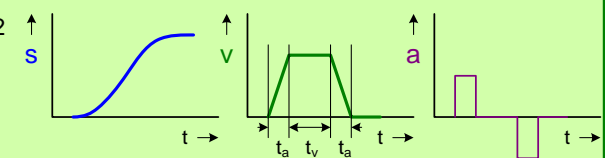**First principle** model: a model based on **theoretical** principles.

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 $t_{top\ floor}$ elevator

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

Position in case of uniform acceleration:

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

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

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

$$S(t_a) = \frac{1}{2} * a_{max} * t_a^2$$
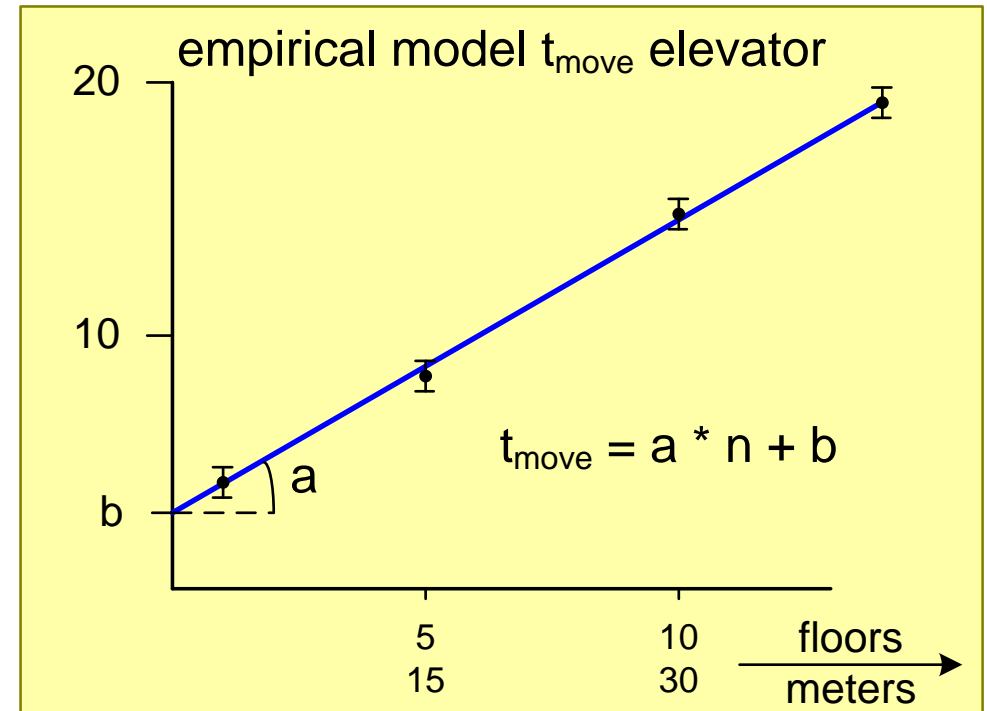
$$S_{linear} = S_{top\ floor} - 2 * S(t_a)$$

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

Empirical Models

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

An empirical model *describes* the observations.

An empirical model provides **no understanding**.

empirical model t_{move} elevator

$$t_{move} = a * n + b$$

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**.

conceptual model t_{move} elevator

$$t_{move} = v_{max} * n + b_{start/stop}$$

$$b_{start/stop} = f(acceleration, jerk)$$
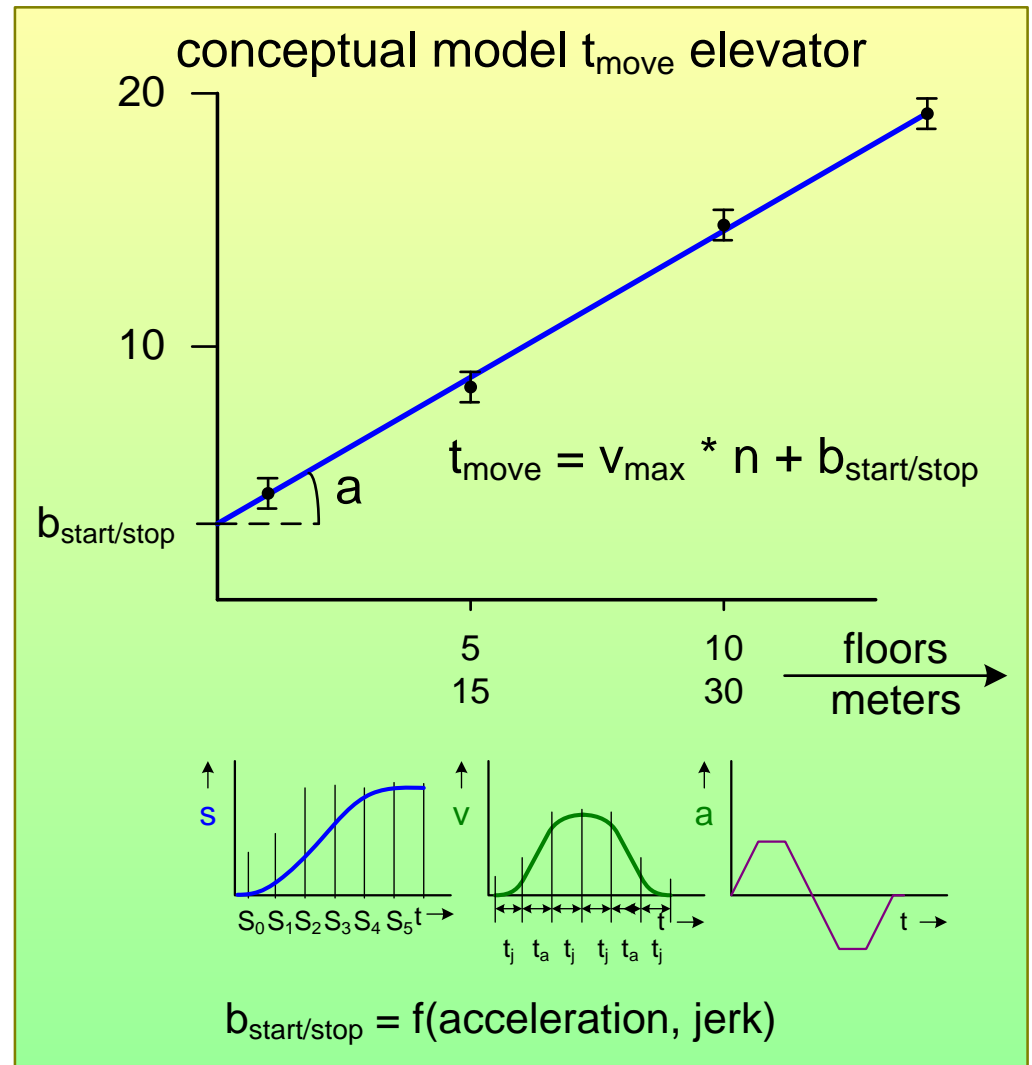
Mental Models

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

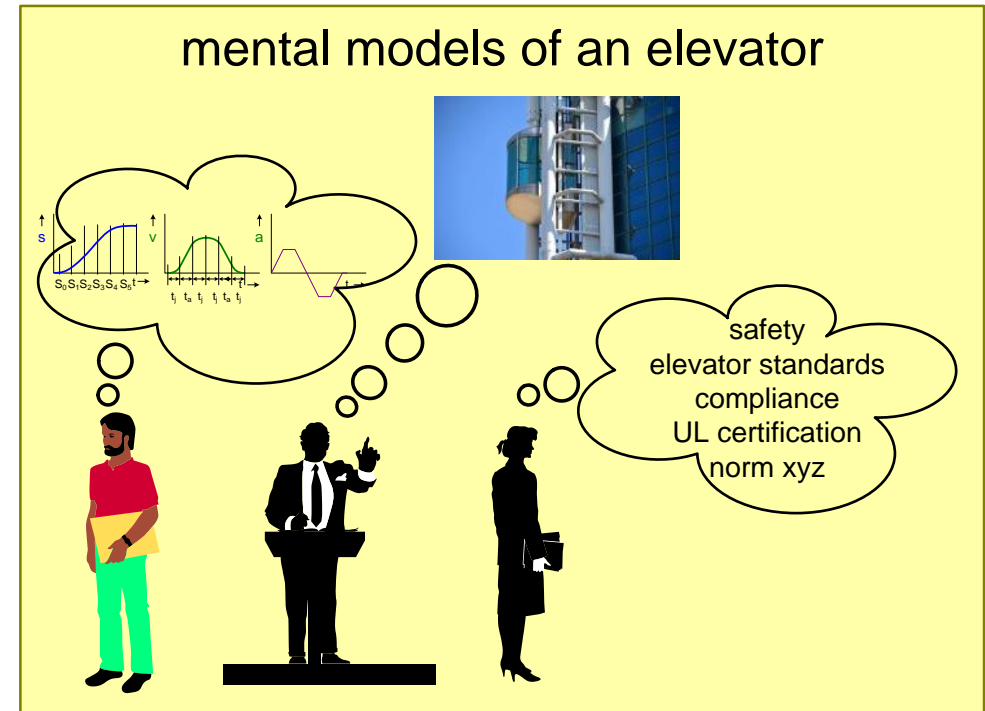Mental models help us to **think**.

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

mental models of an elevator

safety
elevator standards
compliance
UL certification
norm xyz

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/s2

t (s)	s (m)	v (m/s)	a (m/s2)
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
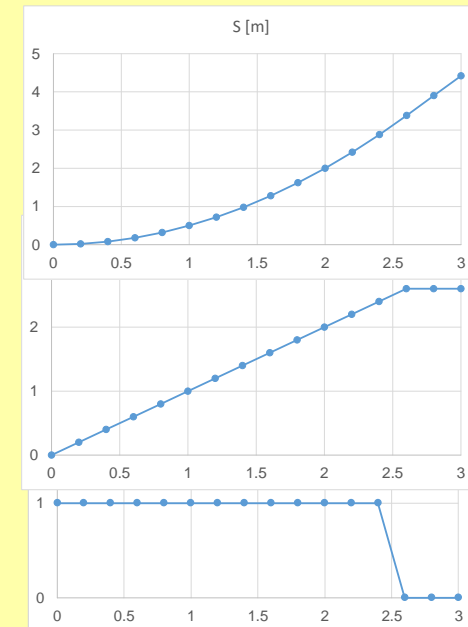
Product Structure and Documentation

The **Product Structure** prescribes the **parts hierarchy**. Each part in the hierarchy has associated **documentation** and **information** for the entire **life cycle.**
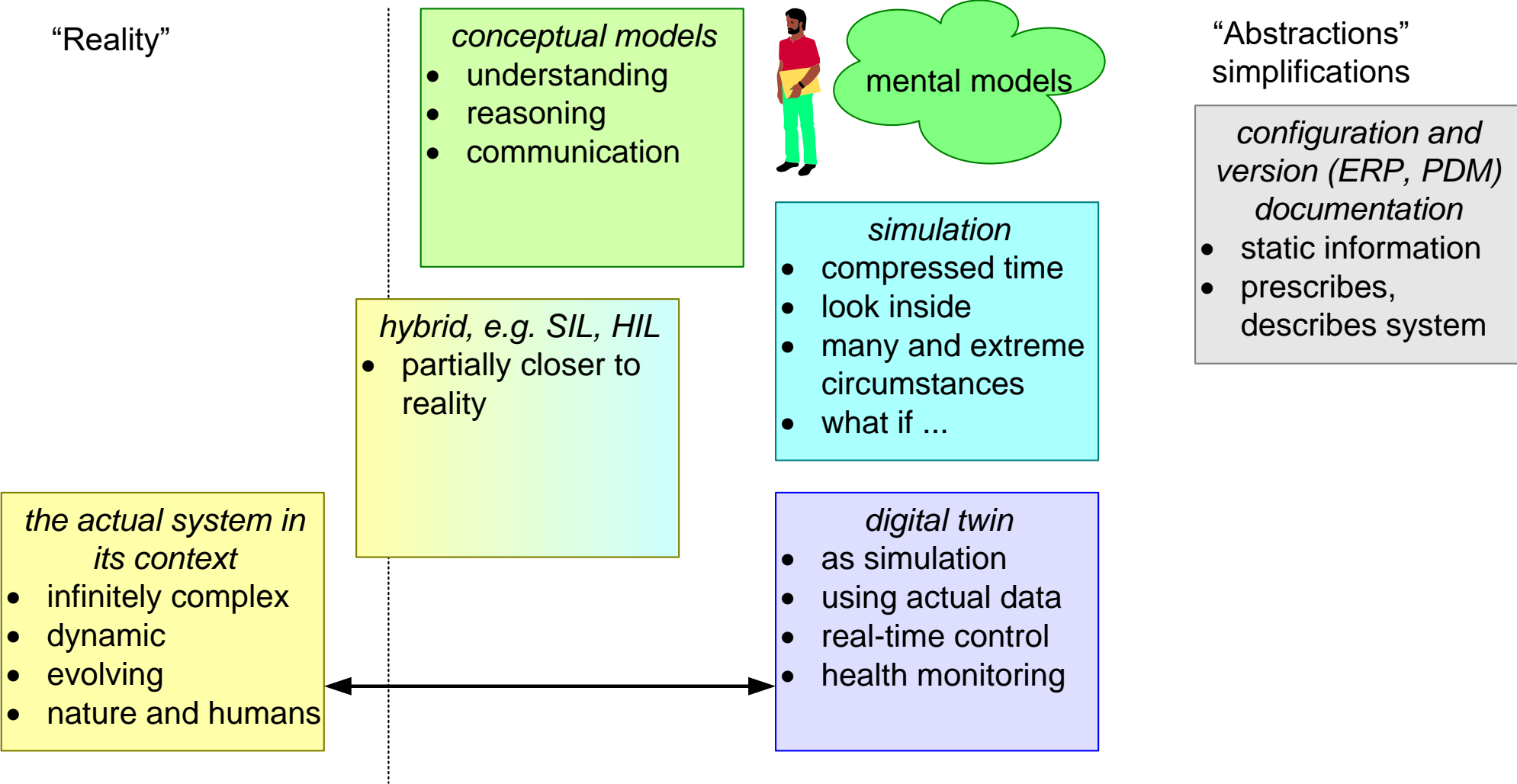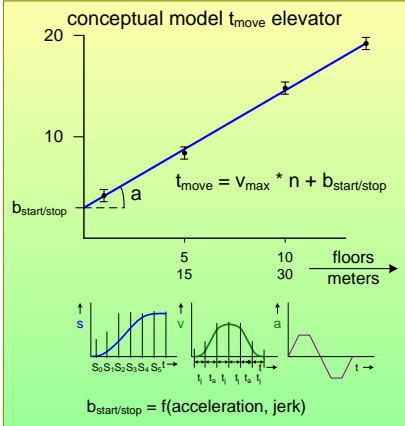
The Product Structure and associated documentation help the organization to *manage* all processes from creation to decommissioning and recycling, via **ERP**, **PDM**, **PLM** etc. systems.

product structure of an elevator
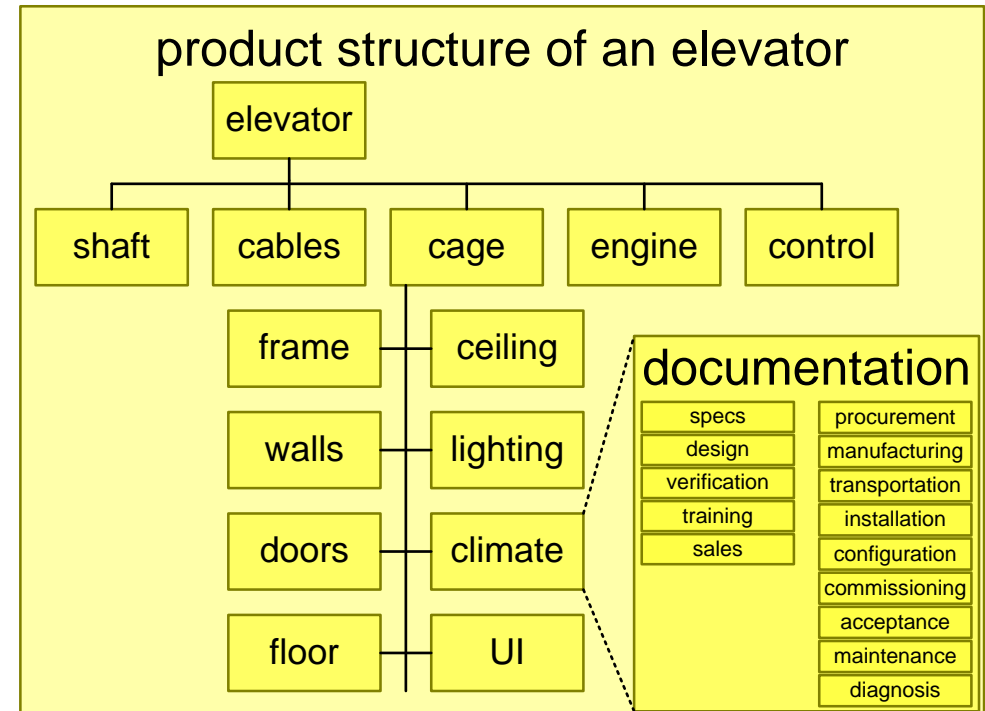
Map of Various Model Types

"Reality"

"Abstractions" simplifications

conceptual models
- understanding
- reasoning
- communication

mental models

configuration and version (ERP, PDM) documentation
- static information
- prescribes, describes system

simulation
- compressed time
- look inside
- many and extreme circumstances
- what if ...

hybrid, e.g. SIL, HIL
- partially closer to reality

the actual system in its context
- infinitely complex
- dynamic
- evolving
- nature and humans

digital twin
- as simulation
- using actual data
- real-time control
- health monitoring

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Conceptualization Reduces 3 to 5 Orders of Magnitude

data increase

implementation *10..100

conceptual dynamics

    -> full space * 100..1000

conceptual model

3 to 5 orders
of magnitude

abstraction /
conceptualization

simulation
(executable model)

conceptual model t_{move} elevator

$t_{move} = v_{max} * n + b_{start/stop}$

$b_{start/stop}$ = f(acceleration, jerk)

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

simulation of an elevator

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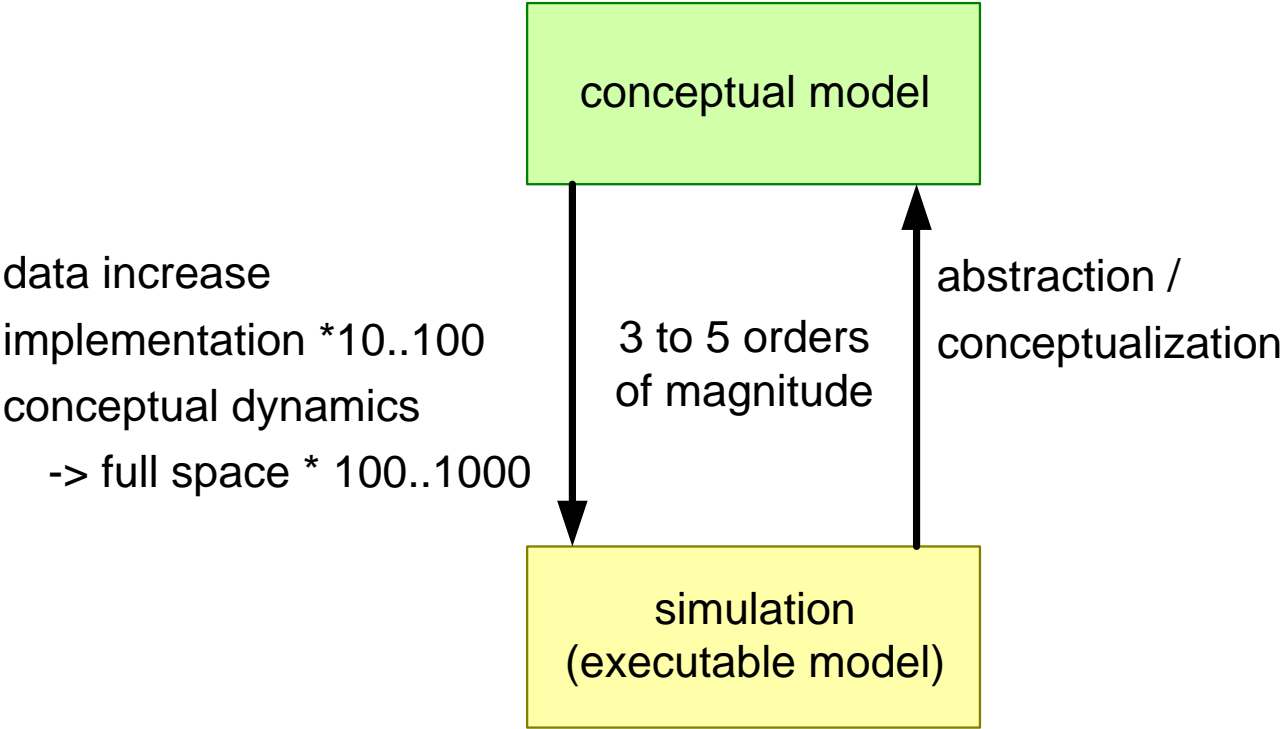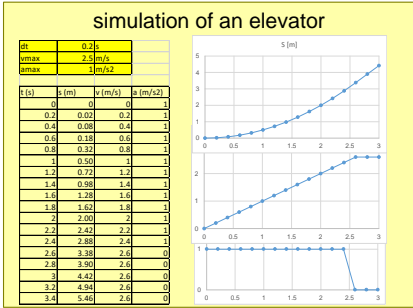
Conceptual Models are at All Levels

customer value proposition

business proposition

drives

drives

system requirements

drives

design and technology

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