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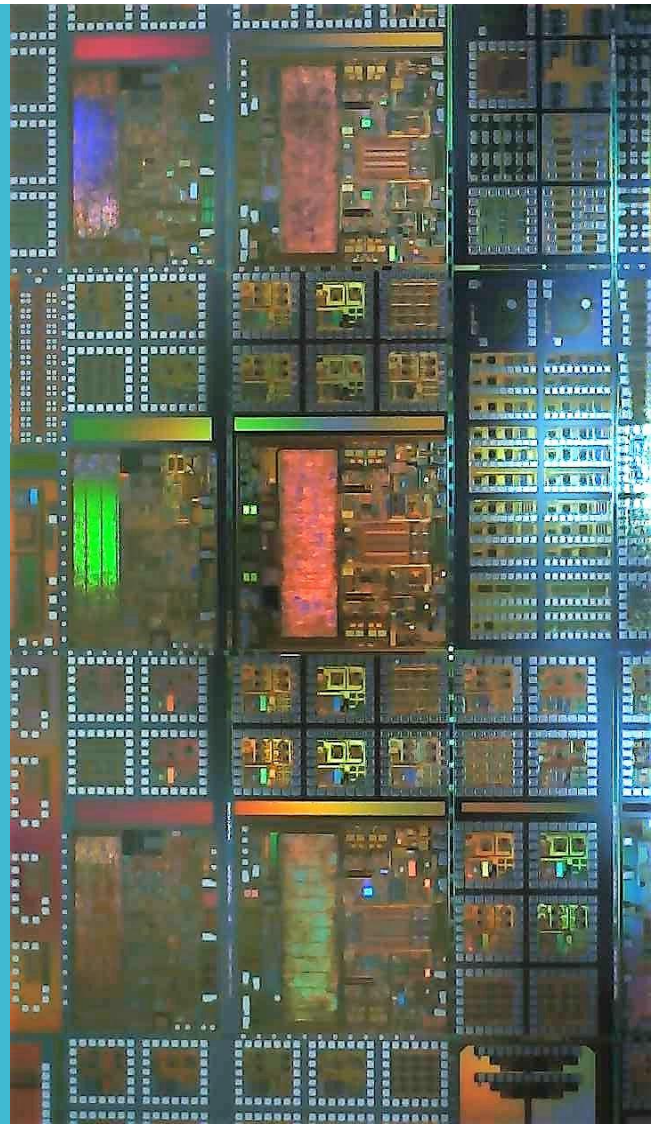
FACULTAD DE INGENIERÍA

Integración de sistemas CMOS

Martín Carrá / Hernán Romero / Mariano García Inza /
Benjamín Reyes / Patricio Pérez Preiti / Pablo Gardella



ALLEGRO microsystems

Presentación de la materia

Objetivo de la materia

- Comprender cómo, a partir de una serie de necesidades, se generan requisitos ('requirements') y restricciones ('constraints'), y cómo estos sirven como base para conceptualizar y desarrollar un circuito de señal mixta en su nivel superior ('top level'). Este proceso debe considerar las interacciones del circuito con el entorno externo, asegurando que cumpla con los requisitos funcionales y de compatibilidad definidos.

Programa sintético

Introducción a la ingeniería en sistemas

- Martín Carrá

Sensores CMOS

- Hernán Romero / Mariano García Inza

Circuitos de Interfaz

- Hernán Romero / Mariano García Inza

Conversores ADC / DAC

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Arquitectura de IC de señal Mixta

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Requerimientos y protecciones ESD

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Introducción a EMC

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Agenda

- Introduction to the Systems Engineering role
- Model Based System Engineering
- Architecture description / Trade studies
- Introduction to requirements and constraints
- Verification and validation

ALLEGRO microsystems

Introduction to Systems Engineering

System Engineering: What is it and why is it useful?

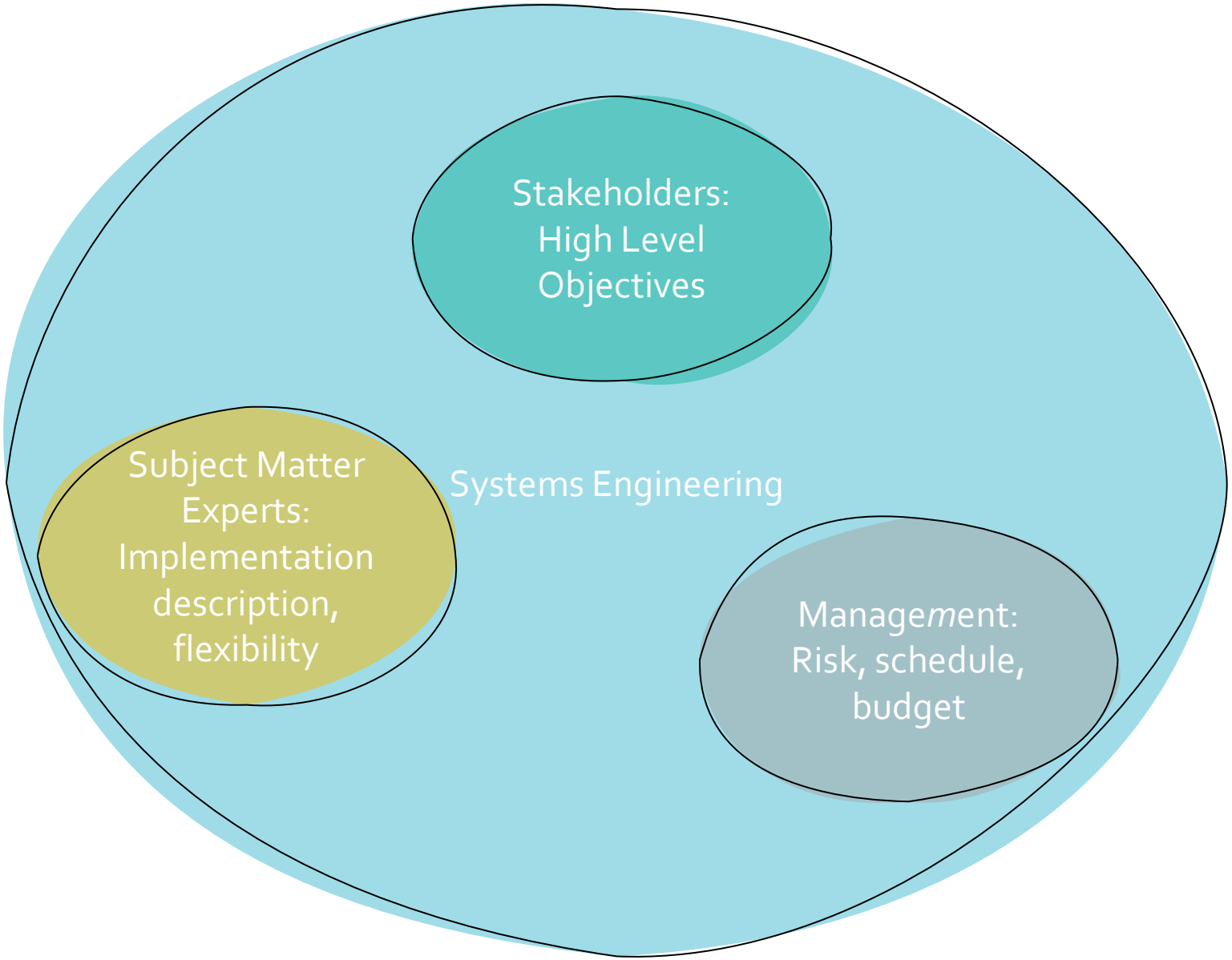
- Systems engineering is a process that we can use to develop something that is **"too complex"** to design and build as a single monolithic entity.

Its guiding the engineering process so that the system can be implemented and meets the needs of the project.

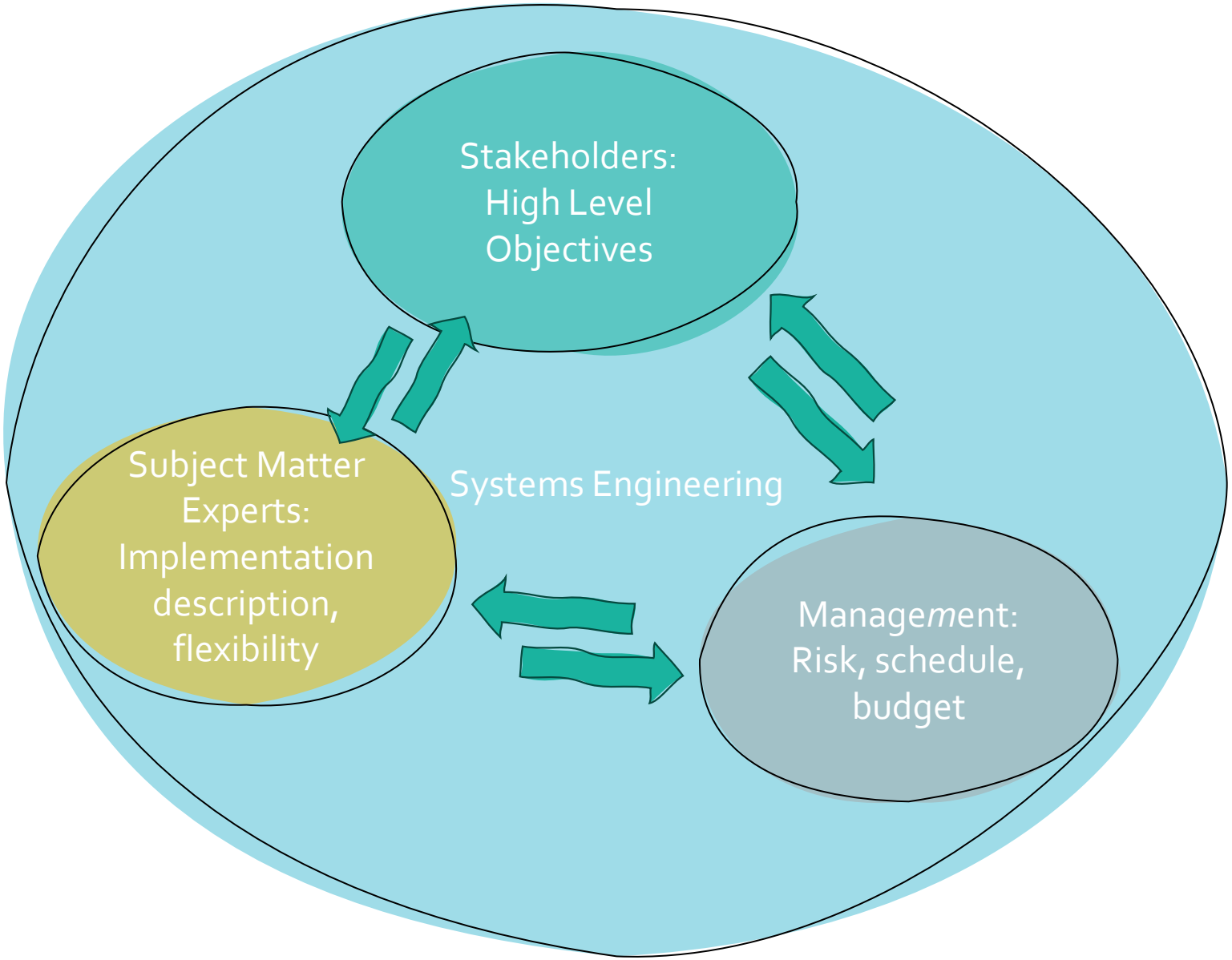
July 16th, 1969

"First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth". Kennedy 1961.

System Engineering: Project needs



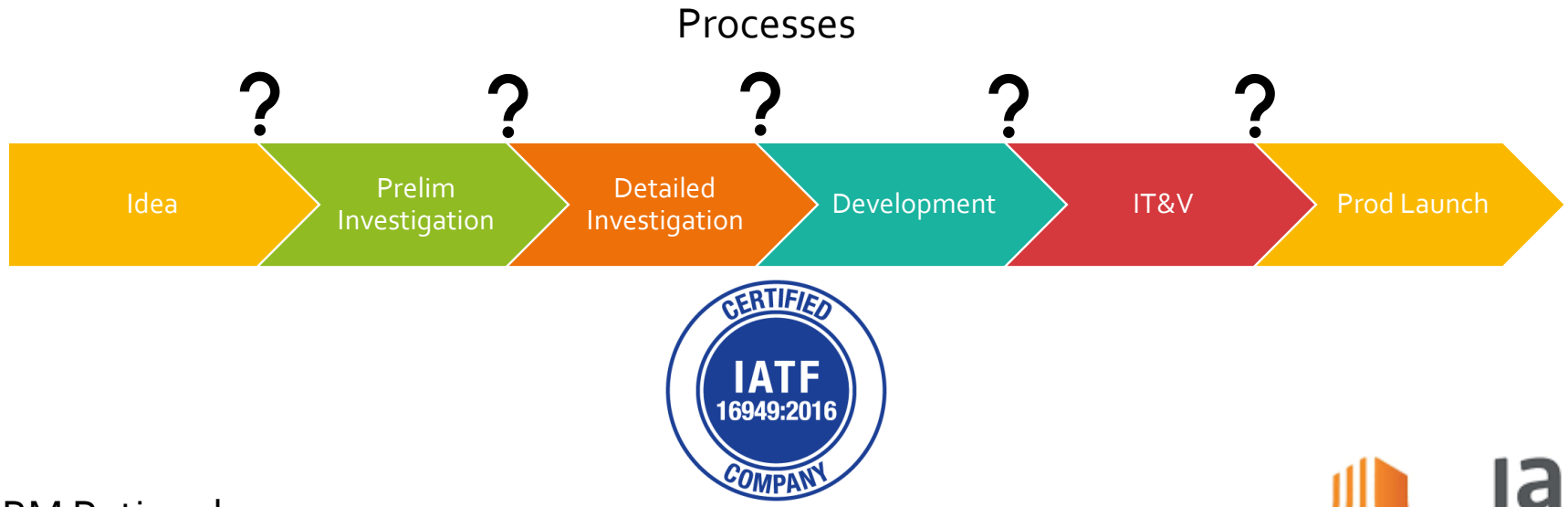
System Engineering: Project needs



System Engineering: Potential problems

- Are these the right components?
- How to model the needs of the higher system
- Are those module compatible to each other?

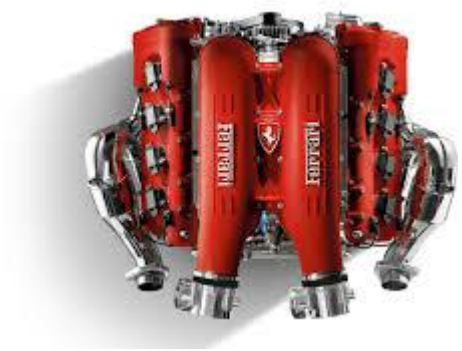
Tools provides ways to model systems and to verify the dependance of the requirements and interfaces



IBM Rational DOORS

Jama software®

Systems engineering: additional work!



Required!

Not required

Valuable?
Meetings about the car:

- Req. reviews
- Wiring schematics
- …

The cost of finding that a requirement is missing after the acceptance of the definition of the product is super expensive.

Necessary for complex systems

Size of the project matters

I want a car door:

- Strong structure
- Hinged
- Latch
- Can be opened from both sides

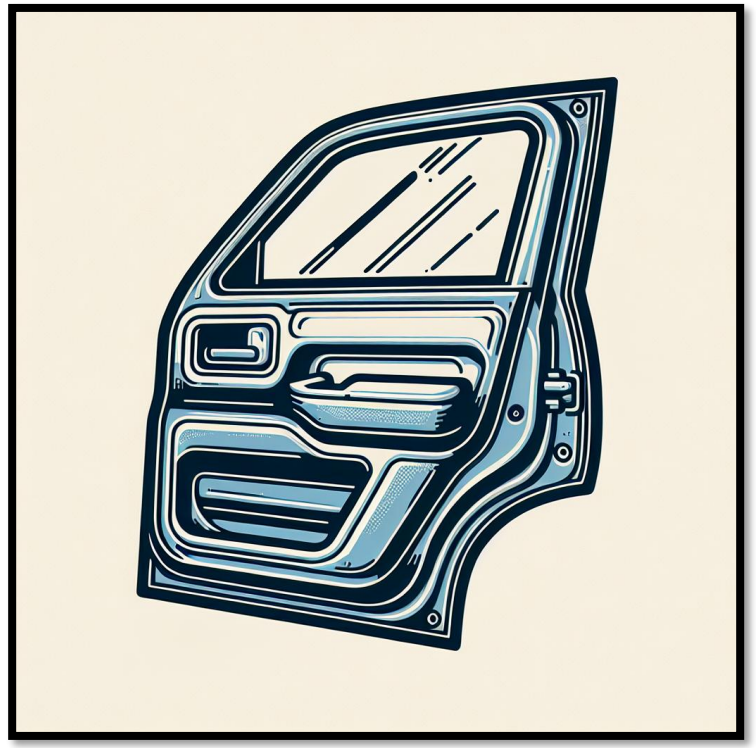
Chat GPT

Size of the project matters

I want a car door:

- Strong structure
- Hinged
- Latch
- Can be opened from both sides
- See out thru the door
- Open the window
- Electric window
- Anti-pinch system

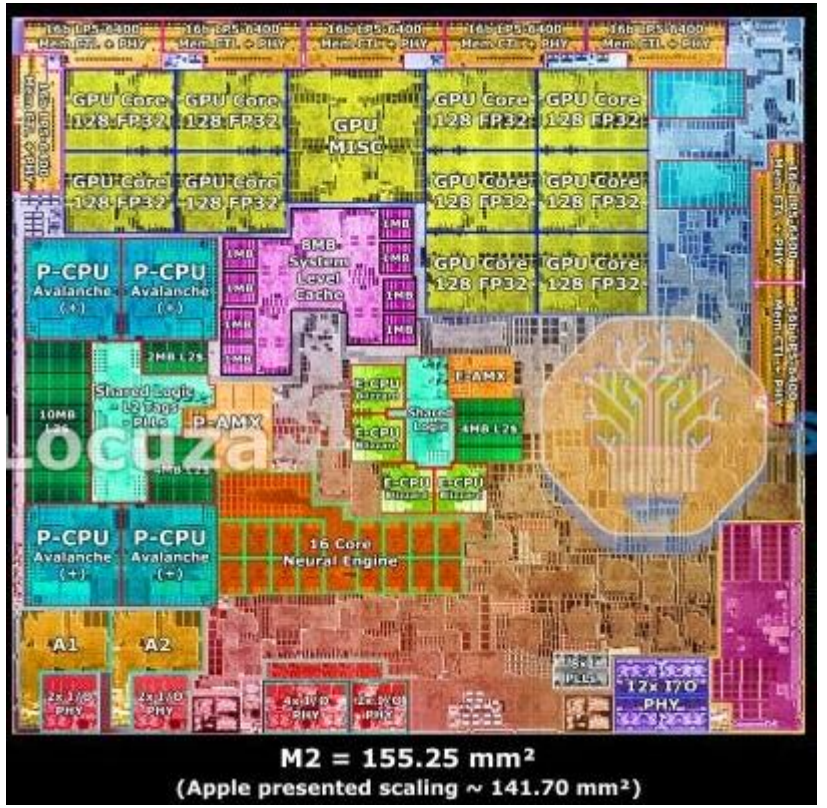
Chat GPT



Size of the Project matters

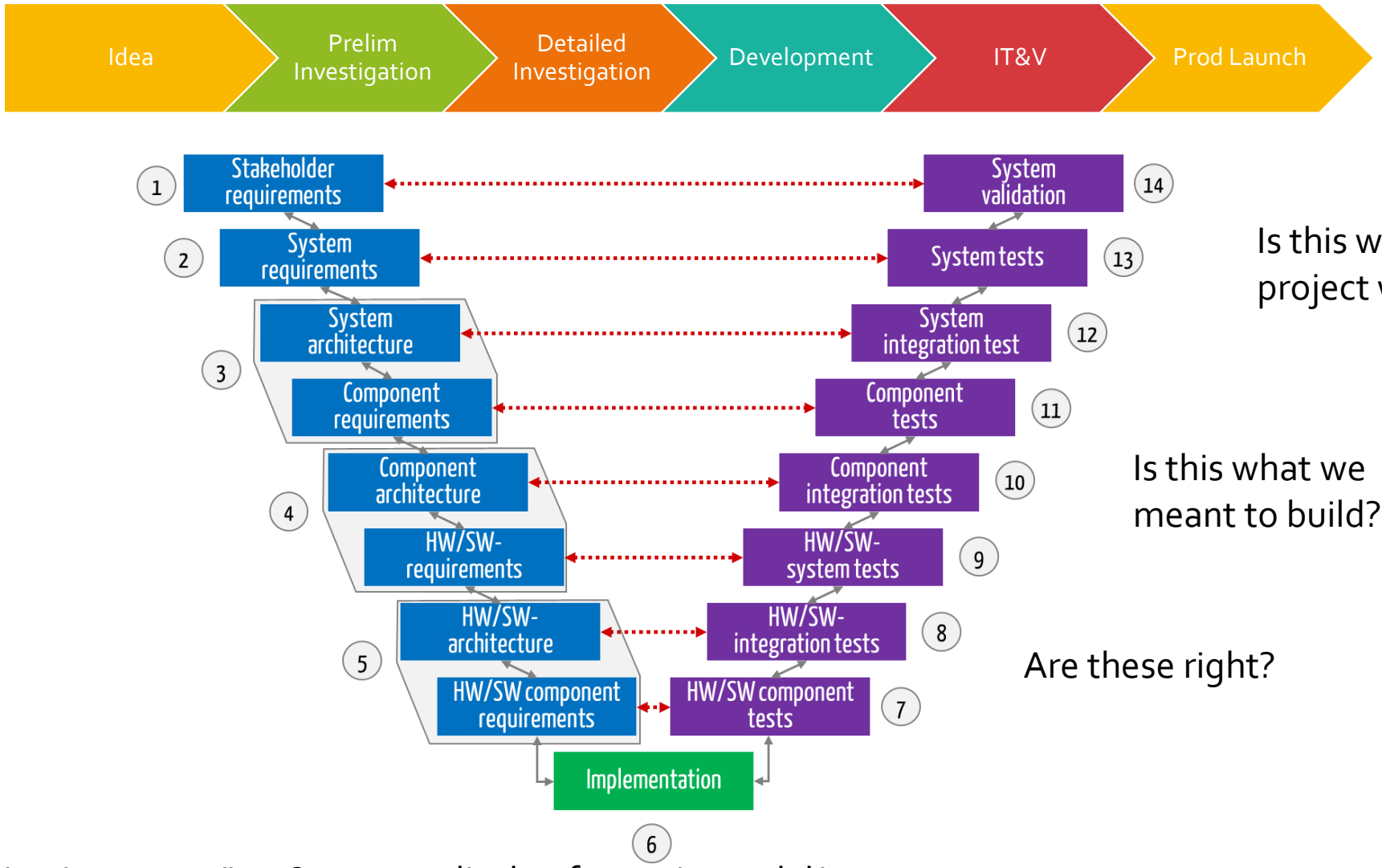
Space Shuttle Program:
2.5 million parts *1

Apple M2 – TSMC N5
~2e10 transistors



[1] https://www.nasa.gov/wp-content/uploads/2023/04/2011.07.05-shuttle-era-facts.pdf
[2] https://semianalysis.com/2022/06/10/apple-m2-die-shot-and-architecture/

System Engineering: Development process



Is this what the project wanted?

Is this what we meant to build?

Are these right?

https://blog.johner-institute.com/iec-62304-medical-software/v-model/

System Engineering: Development process….

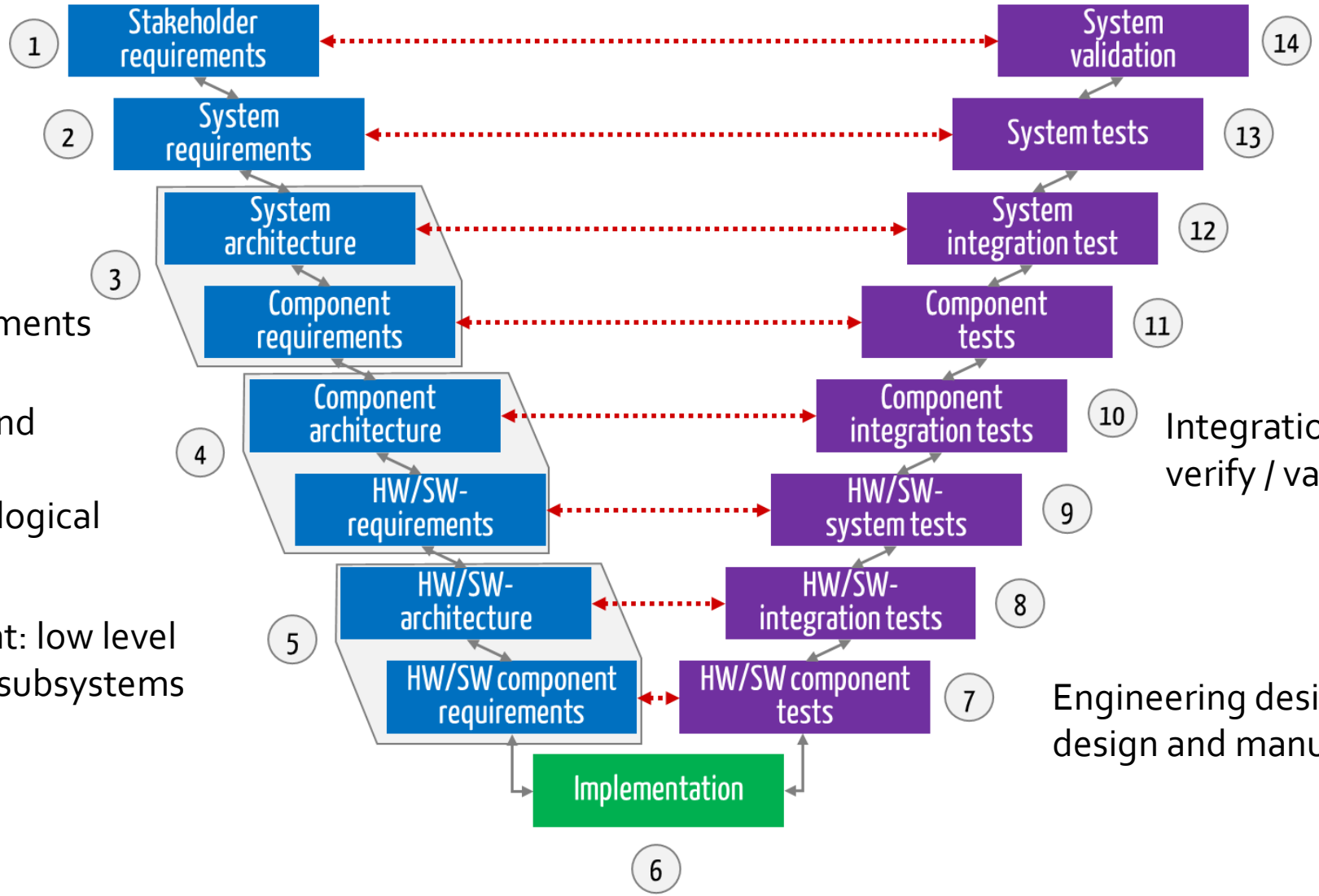
Stakeholder needs:

Concept Exploration

Performance requirements

Functional Analysis and formulation:
Functional, physical, logical arch.

Detailed development: low level requirement / define subsystems configs

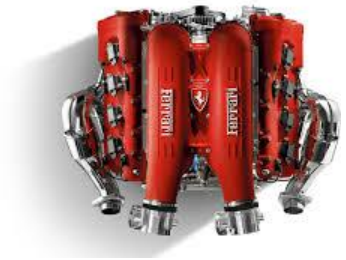


Integration and test: build and verify / validate system

Engineering design: detail design and manufacturing

System Engineering: Concurrent engineering.

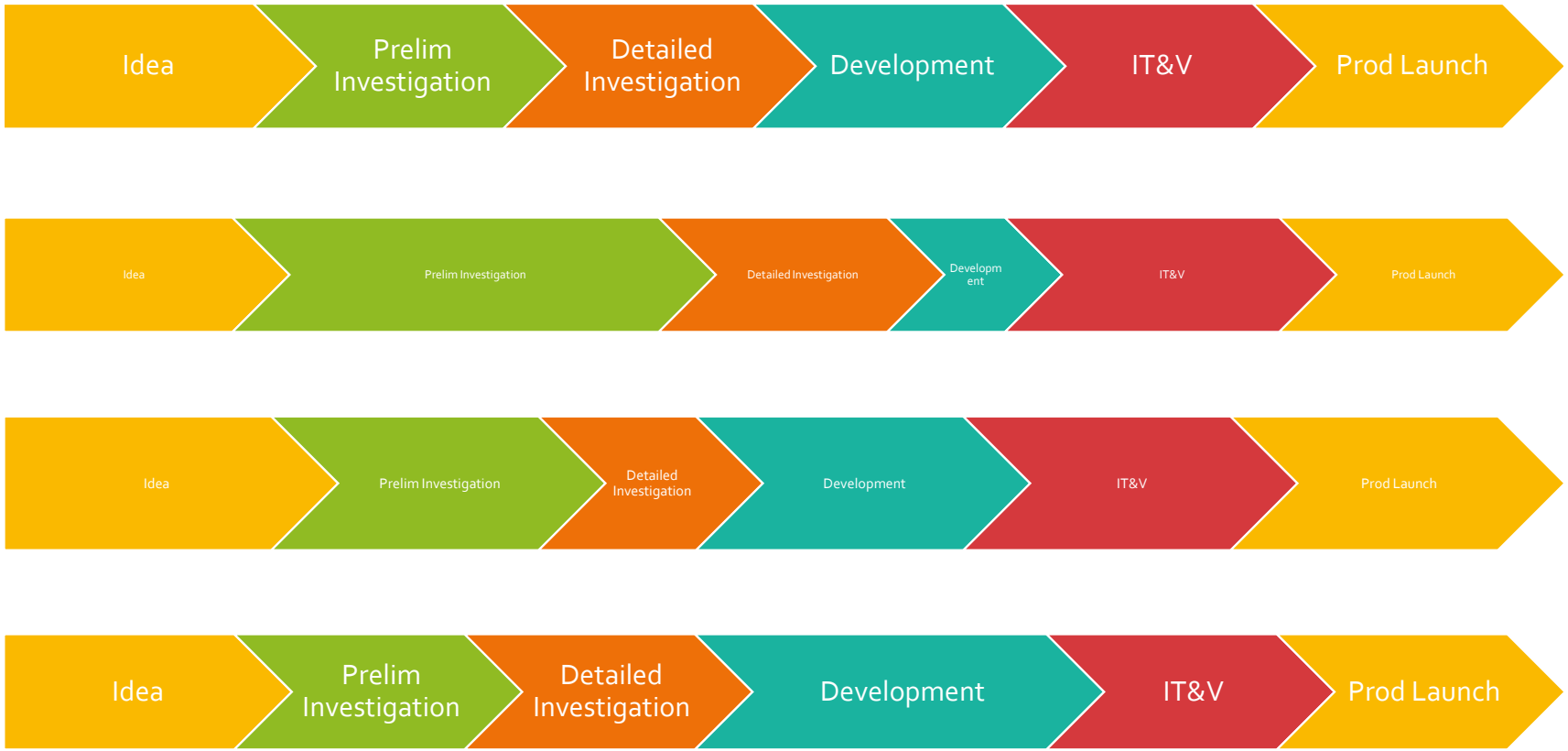
Block / Product



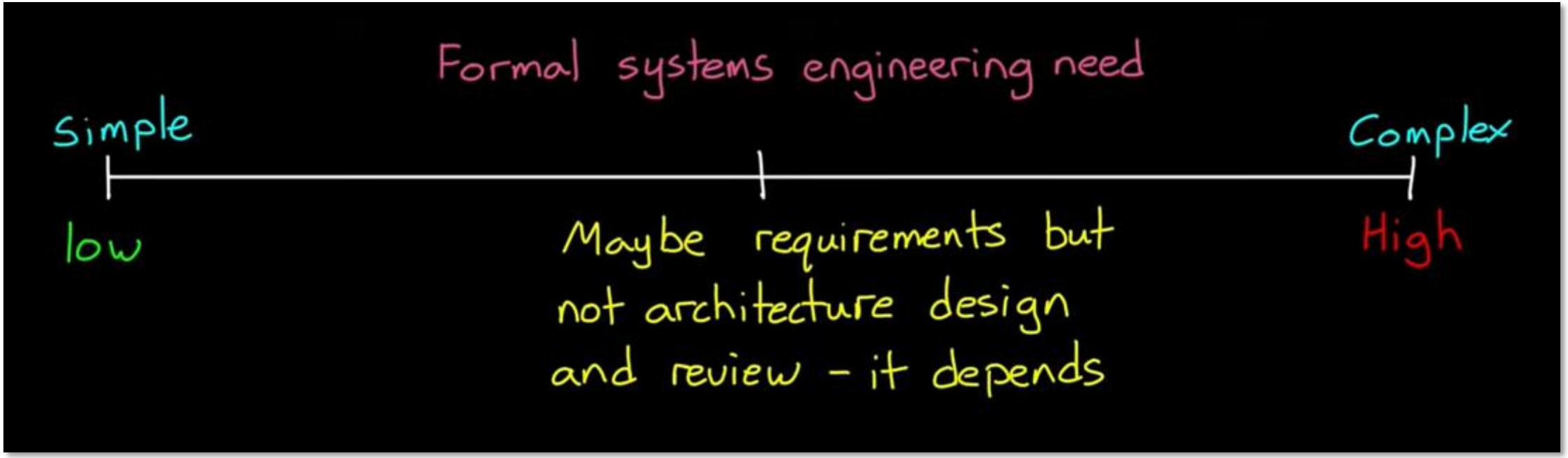
System Engineering: Concurrent engineering.

Block / Product	Idea	Prelim Investigation	Detailed Investigation	Development	IT&V	Prod Launch
Block / Product	Idea	Prelim Investigation	Detailed Investigation	Development	IT&V	Prod Launch
Block / Product	Idea	Prelim Investigation	Detailed Investigation	Development	IT&V	Prod Launch

System Engineering: Concurrent engineering.



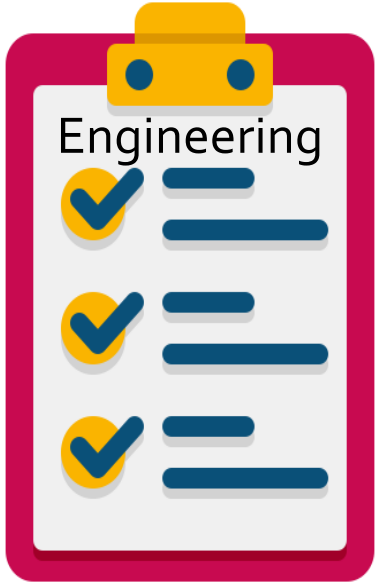
System Engineering: Take away…



Model Based System Engineering

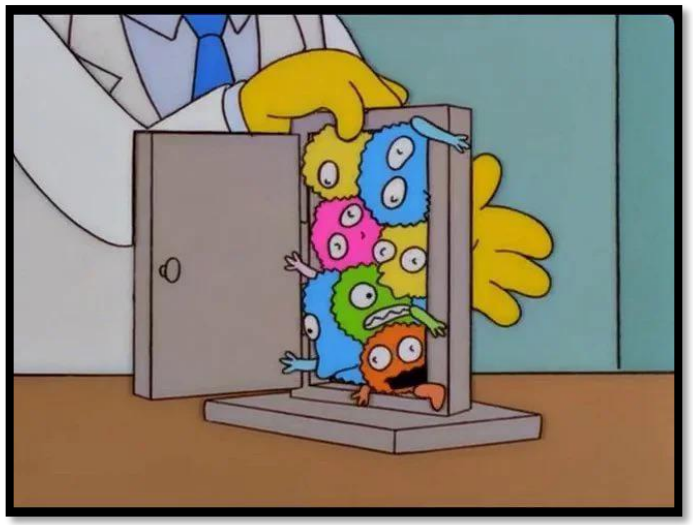
System engineering: optimization problem

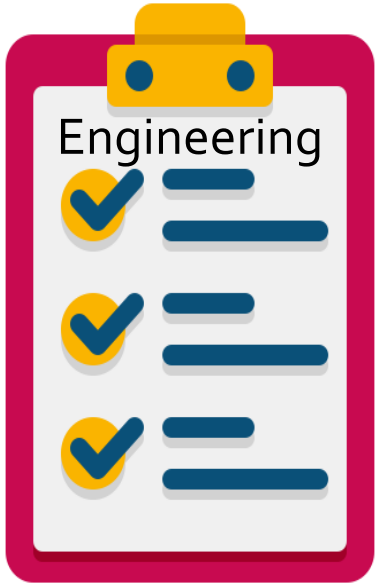
Systems Engineering helps find the balance between everyone's needs.



System engineering

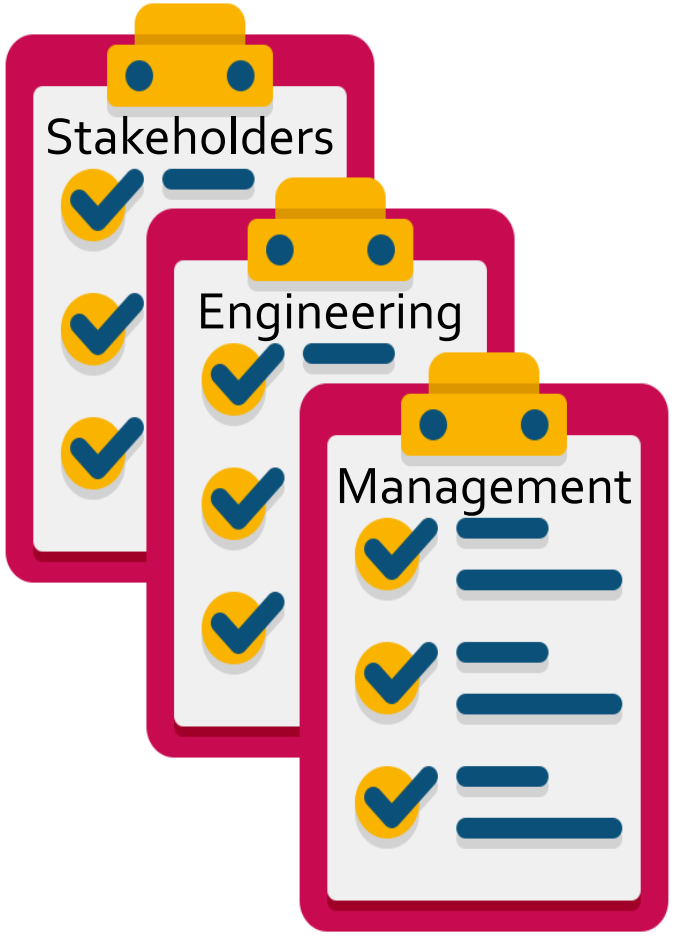
Systems Engineering helps find the balance between everyone's needs.





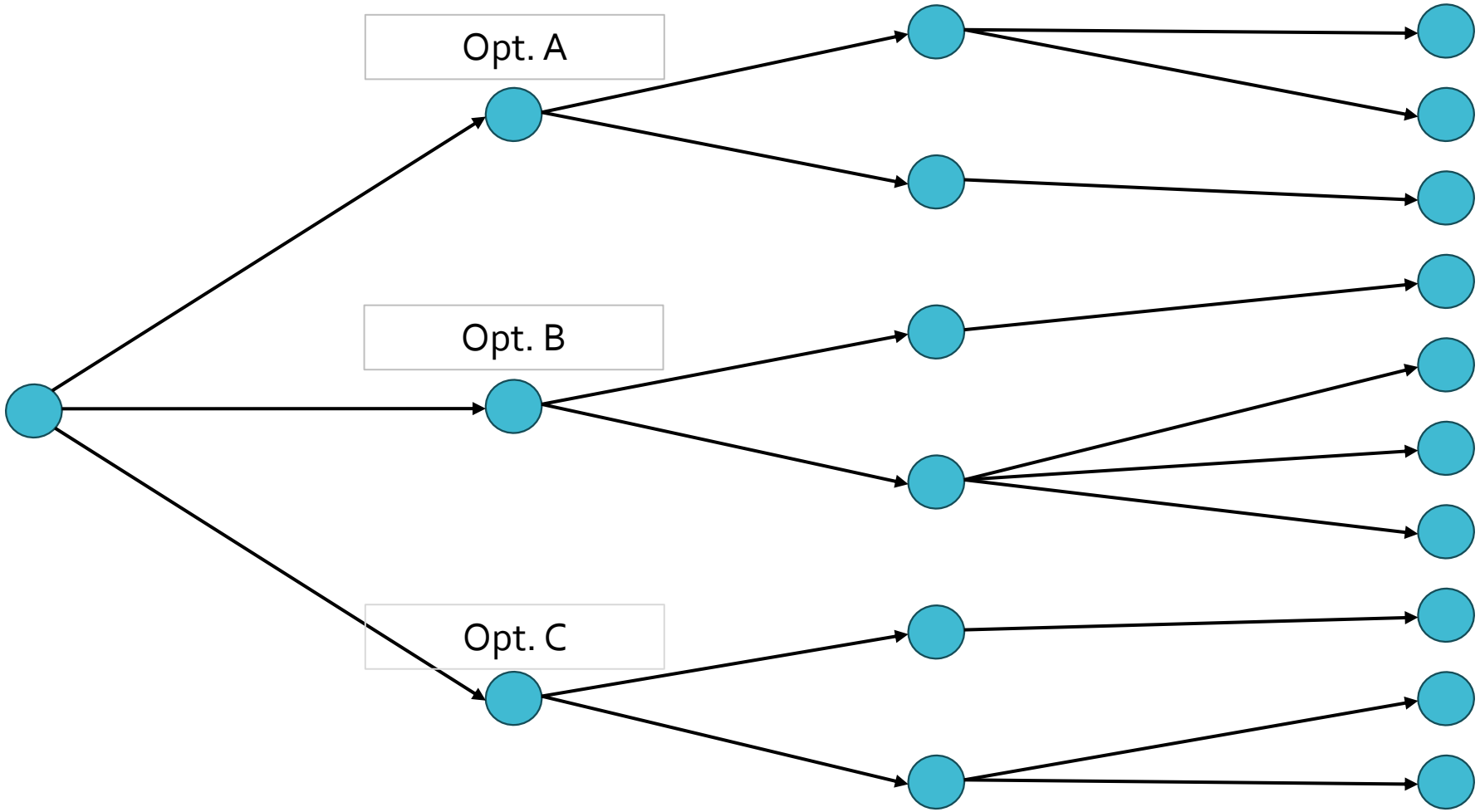
System engineering: Optimization

"Let´s find the absolute best way to balance each of these needs"

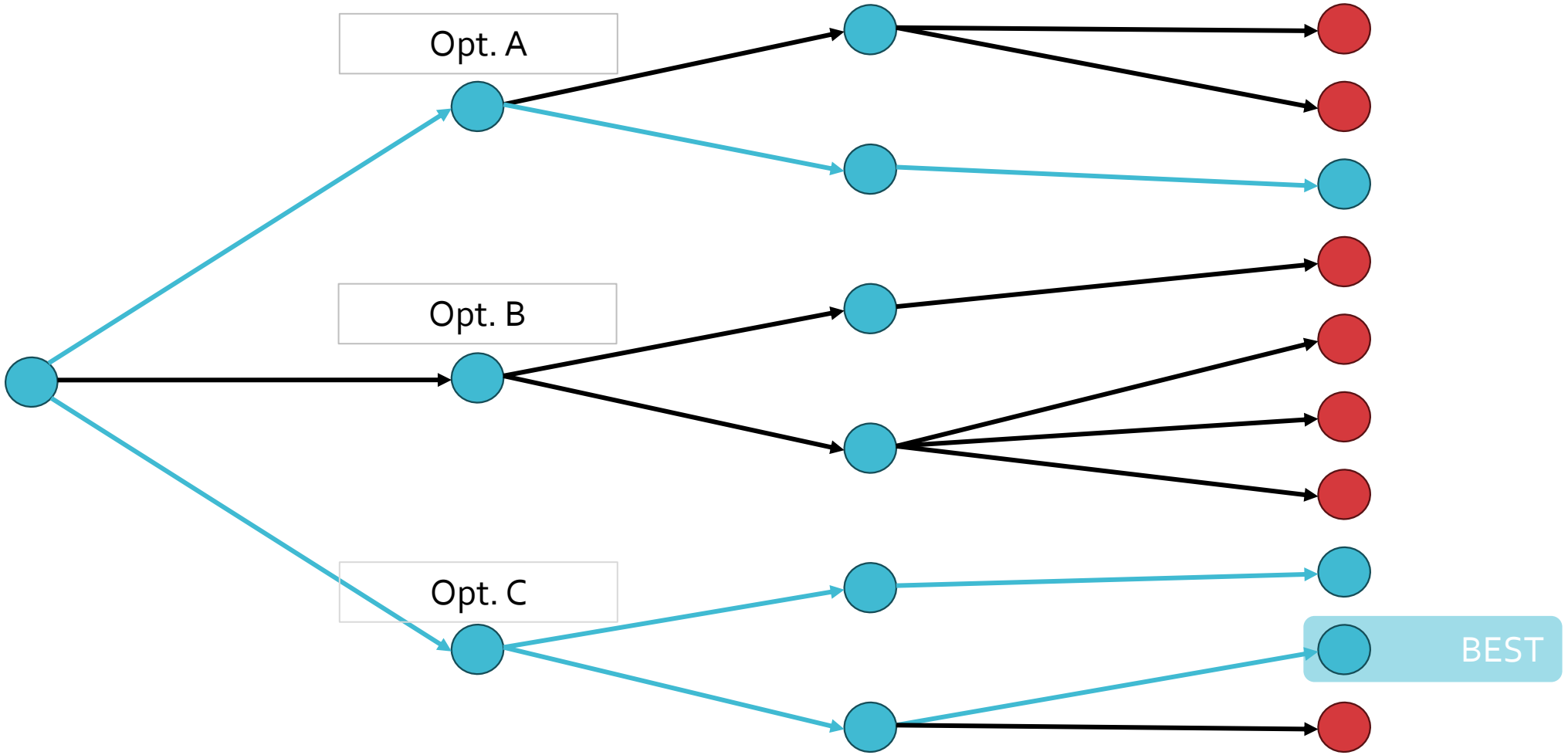


"Suitable solution" < "Best solution"

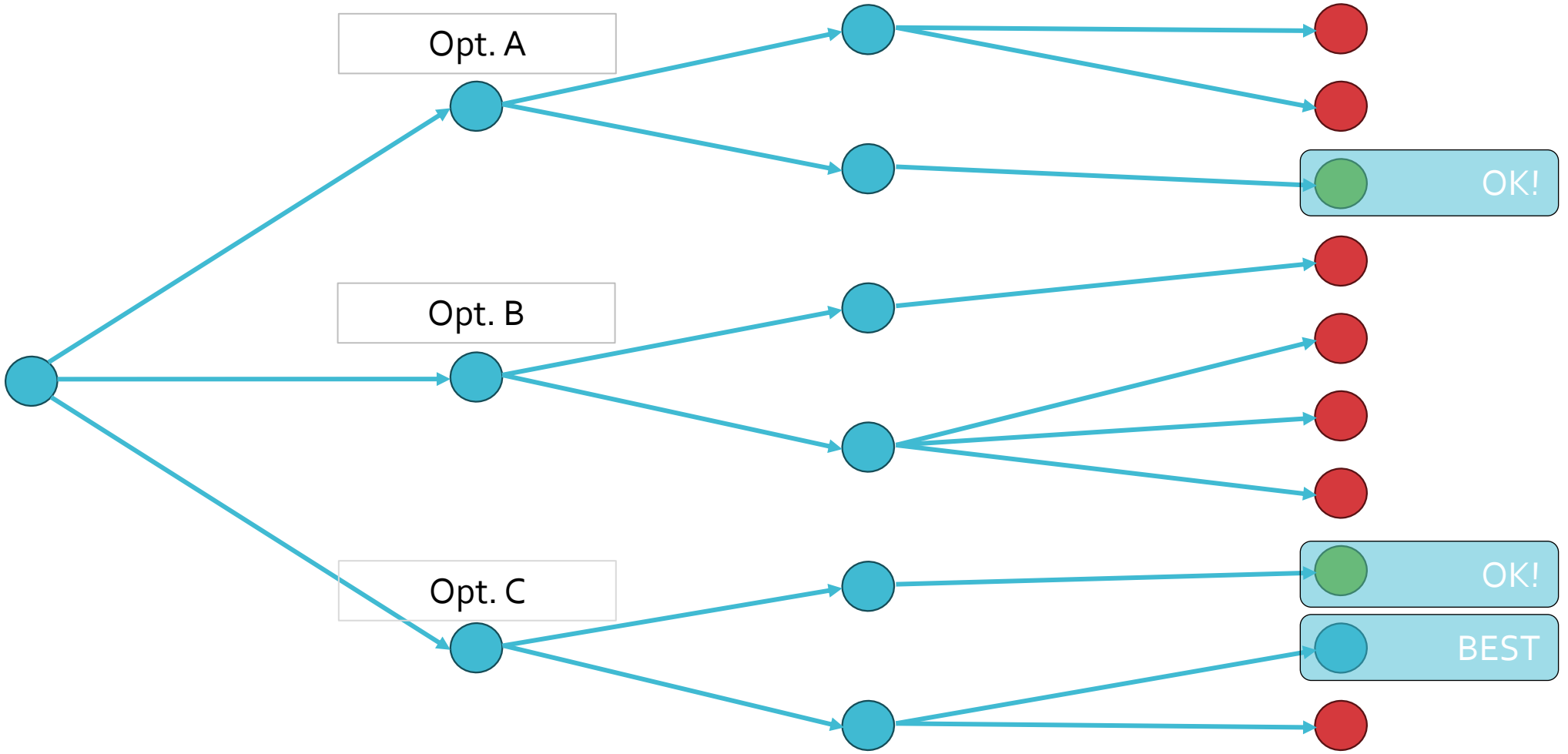
System engineering: Feasibility Analysis.



System engineering: Feasibility Analysis.



System engineering: Feasibility Analysis.



System engineering: explore the option space

Reasonable options? ->

- Has this been done before?
- What's available commercially ?
- What's being researched?
- Team expertise?

System engineering: explore the option space

Reasonable options? ->

- Has this [illegible]e before?
- Wha[illegible]able commercially ?
- [illegible]being researched?

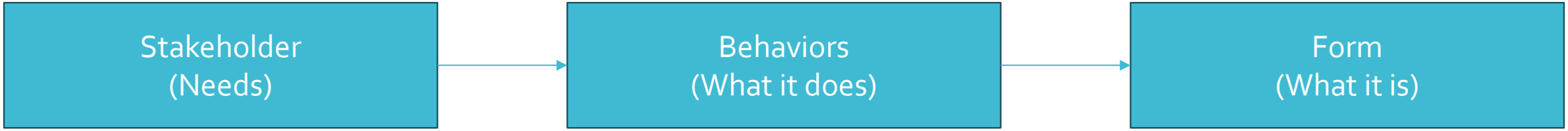
Caution: Engineering bias!!

System engineering: explore the option space

Reasonable options? ->

- Has this been done before?
- What's available commercially ?
- What's being researched?

SE Workflow /Processes



Architecture description / Trade studies

System engineering: explore the option space

Trade Study: is the process of comparing two or more options by judging them on how they balance the project needs

	Input Range	Ripple Rejection	Topology	BOM Count
Option A	5 – 12 V	90 dB	Linear	5
Option B	3.6 – 6 V	120 dB	Linear	10
Option C	3.6 – 20	85 dB	Buck	12

System engineering: explore the option space

Trade Study: is the process of comparing two or more options by judging them on how they balance the project needs

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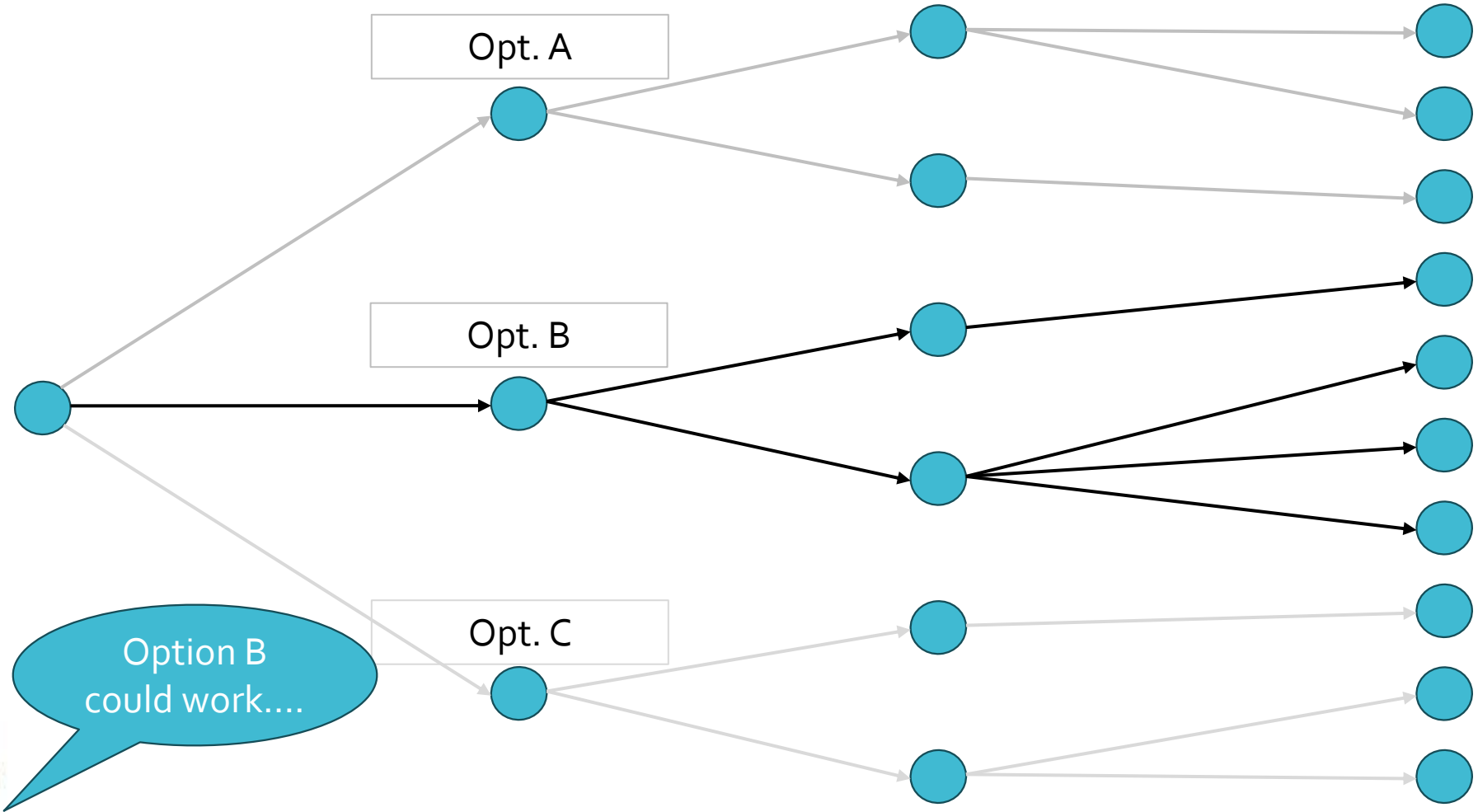
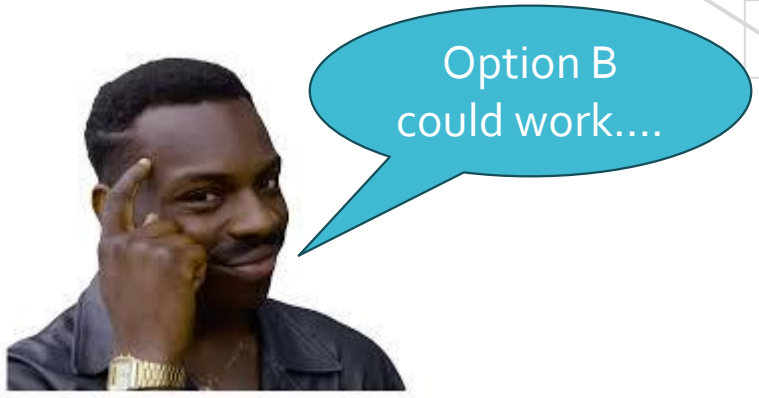
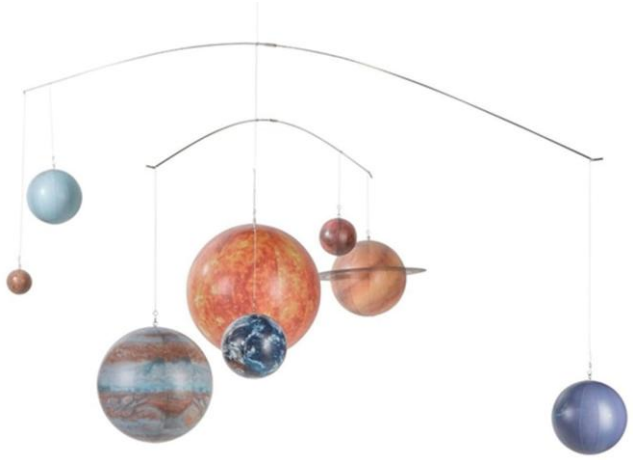
System engineering: Trade Studies / Feasibility Analysis.





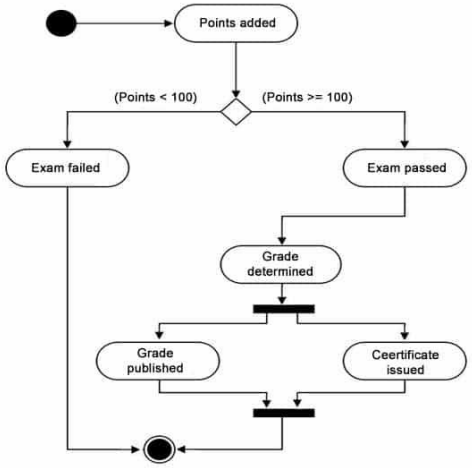
System engineering: System Modeling

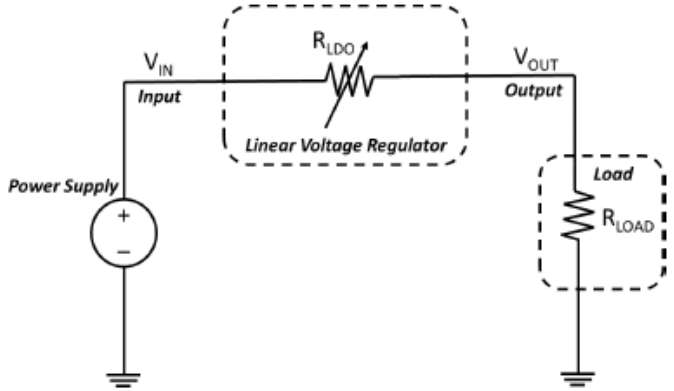
A model is an approximation of the reality.



Physical Model

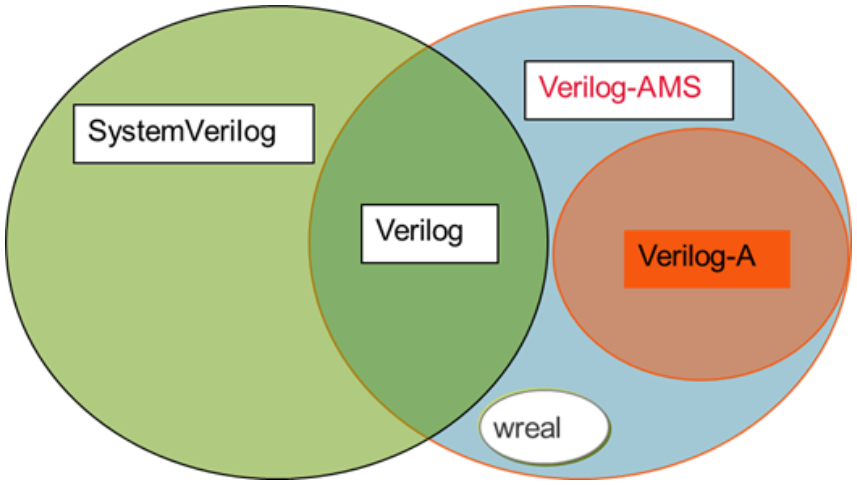
Behavioral Model





Architectural Diagram

System engineering: System Modeling Tools



MATLAB®
SIMULINK®

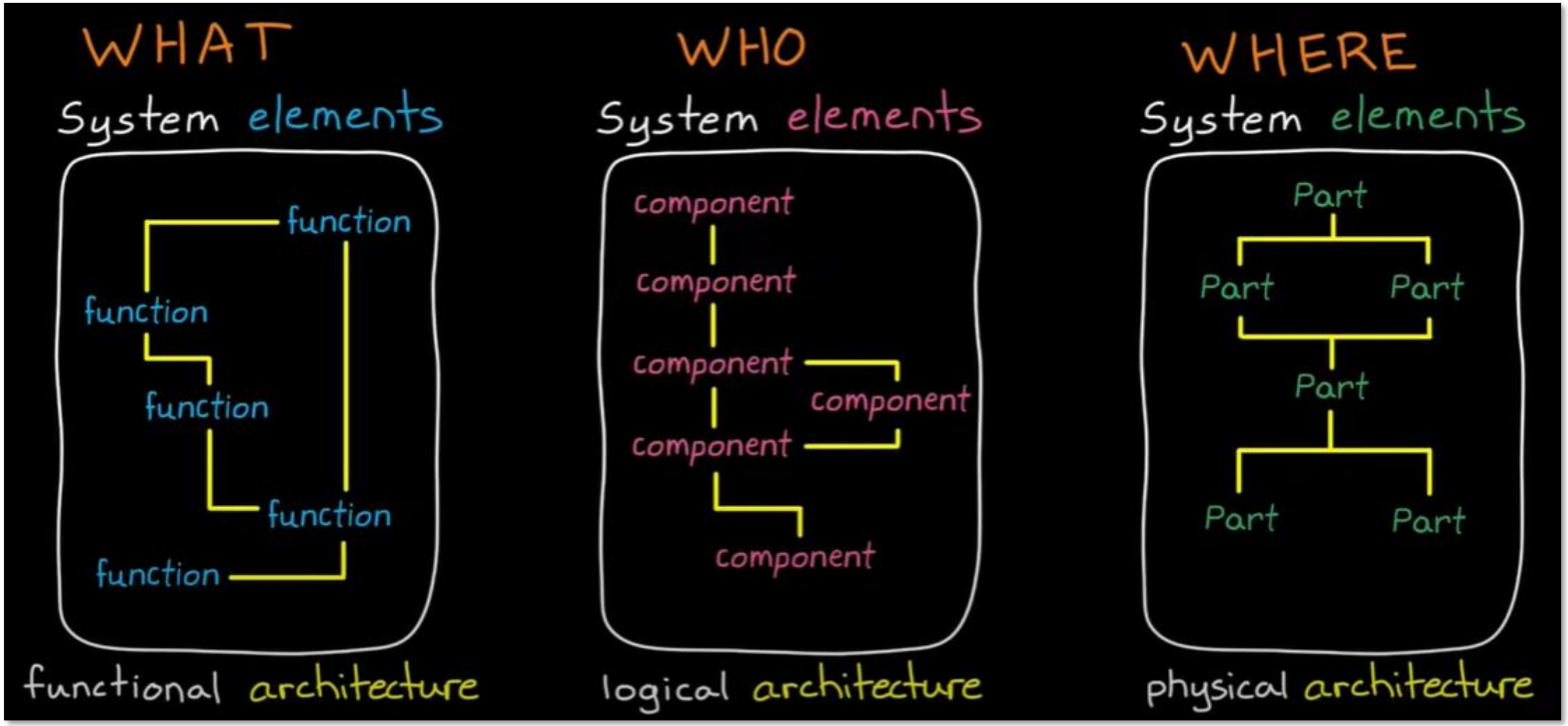
Custom IC Design

Virtuoso

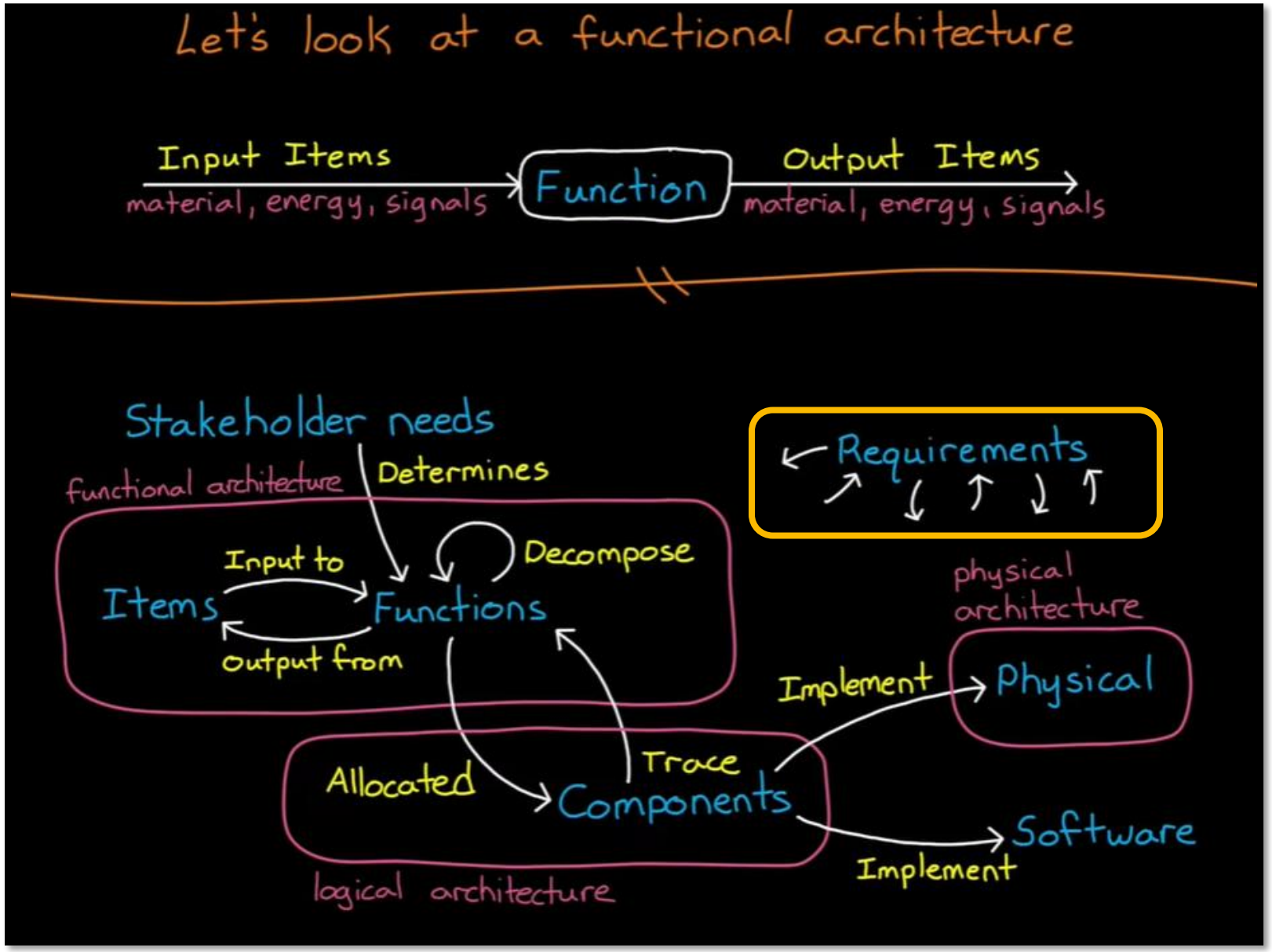
cadence

SYNOPSYS®

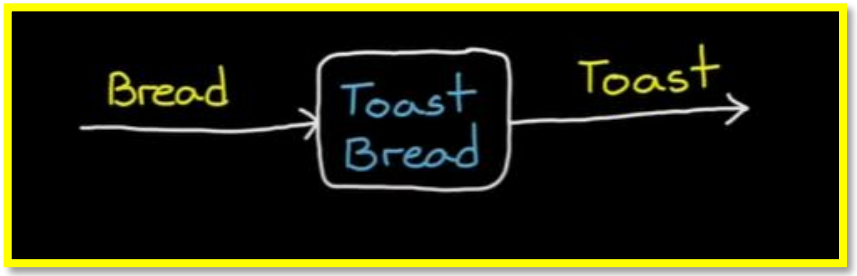
System engineering: what is an architecture?



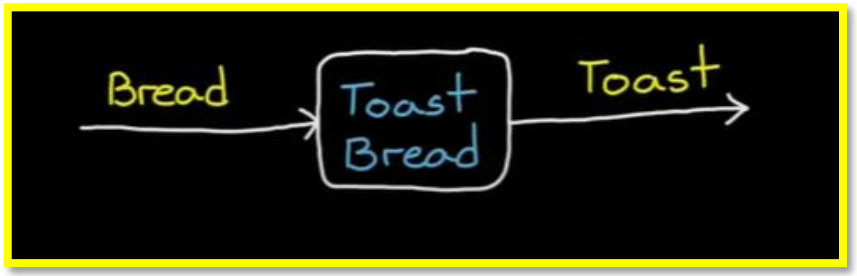
System engineering: what is an architecture?

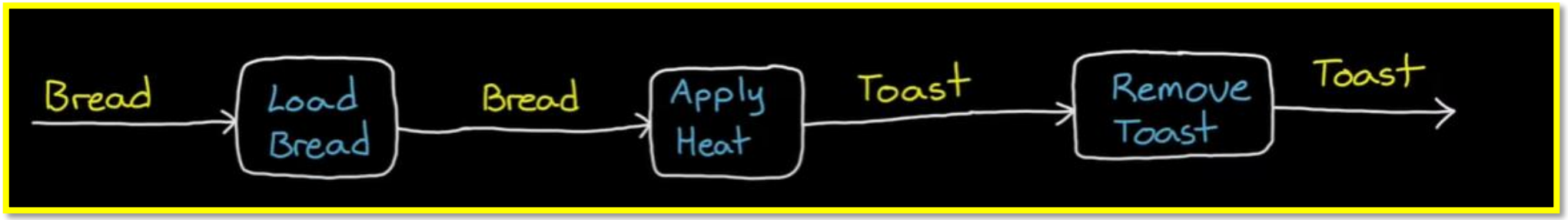


System engineering: what is an architecture?

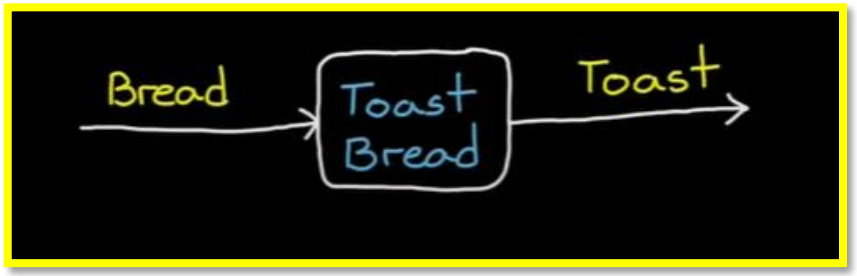


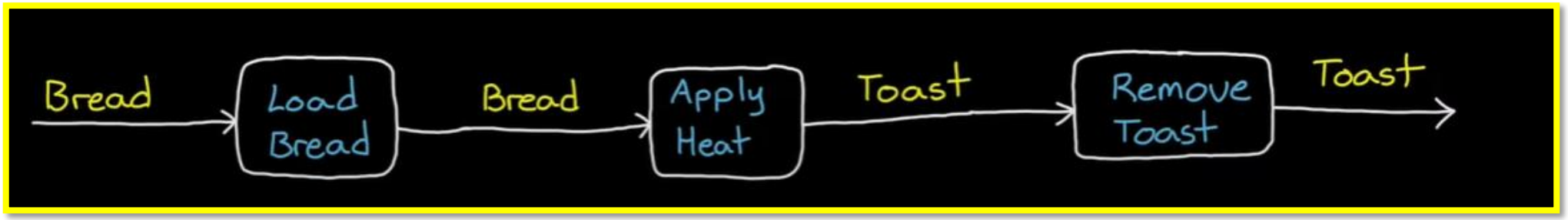
System engineering: what is an architecture?

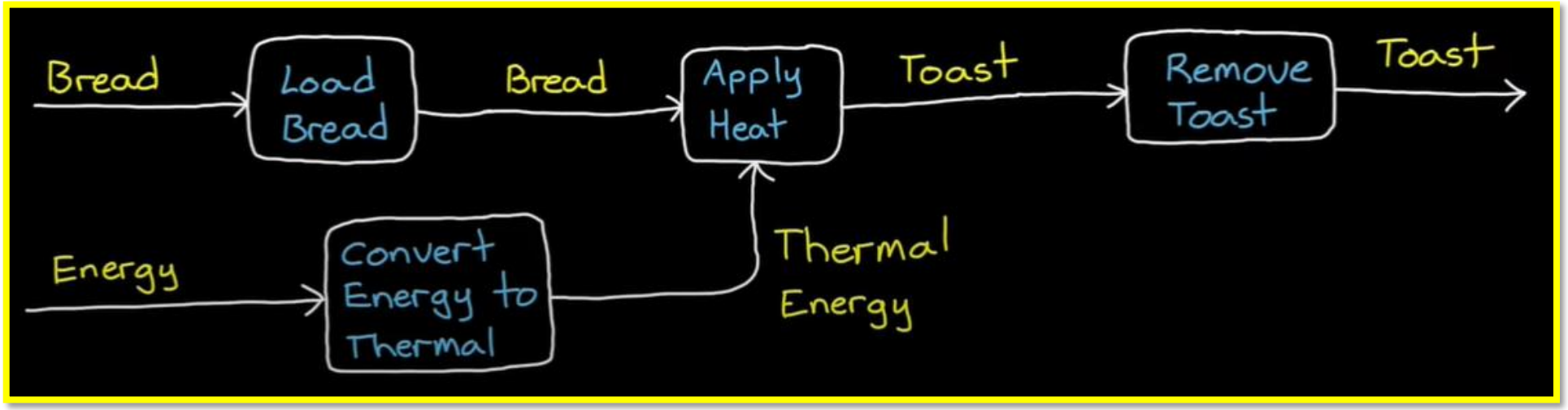




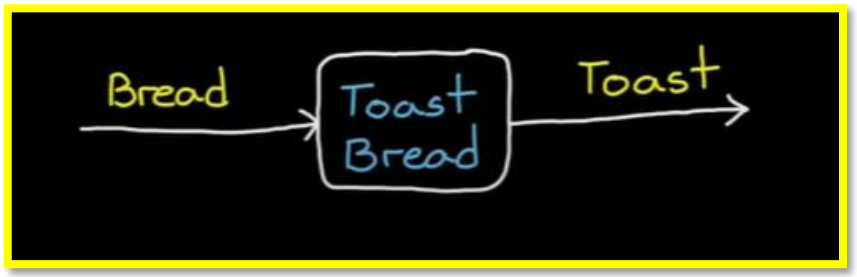
System engineering: what is an architecture?

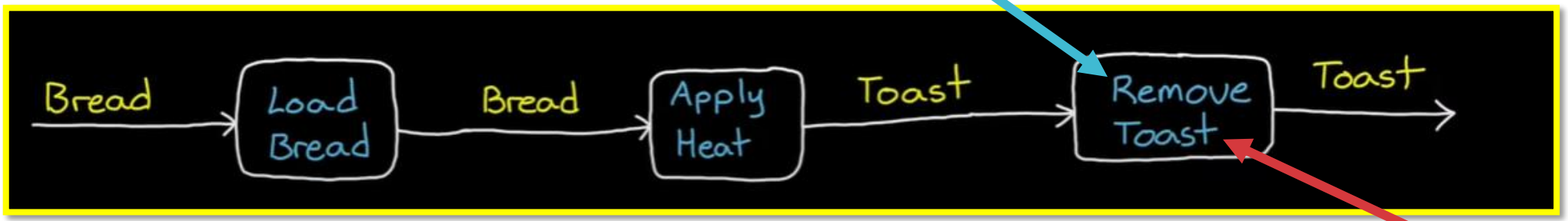


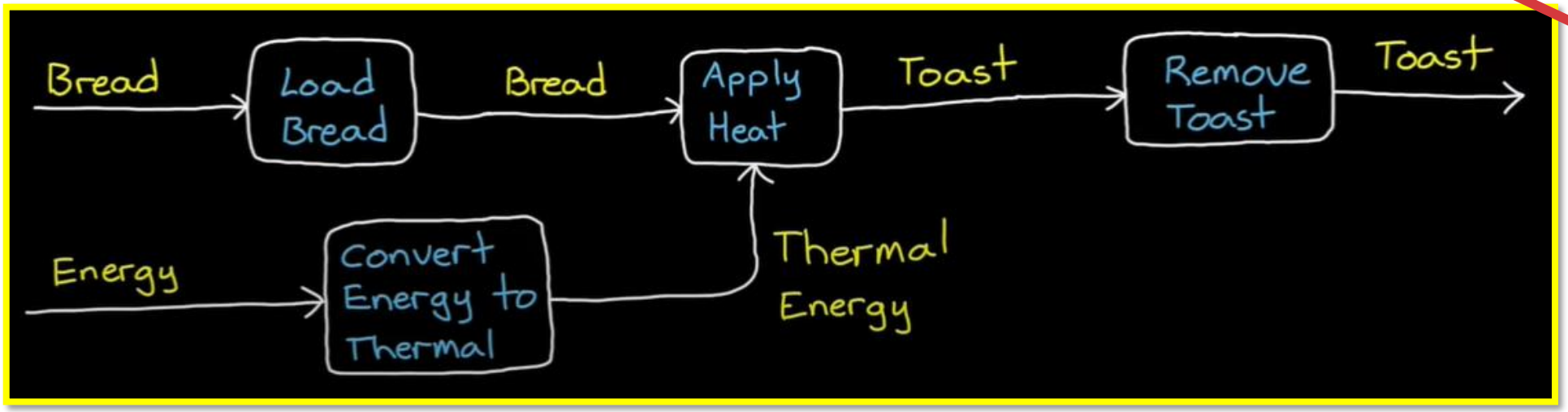




System engineering: what is an architecture?





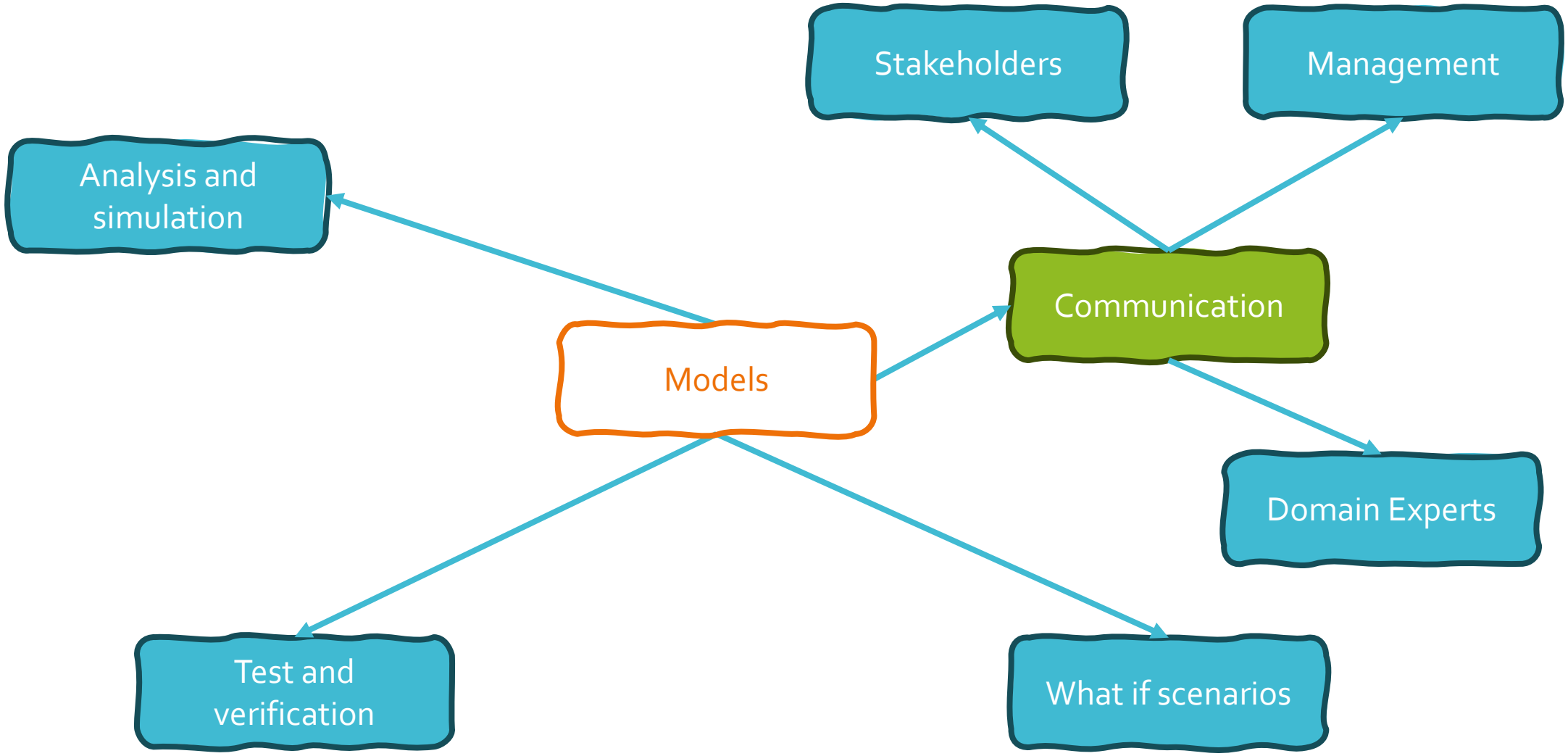


Verb

Noun

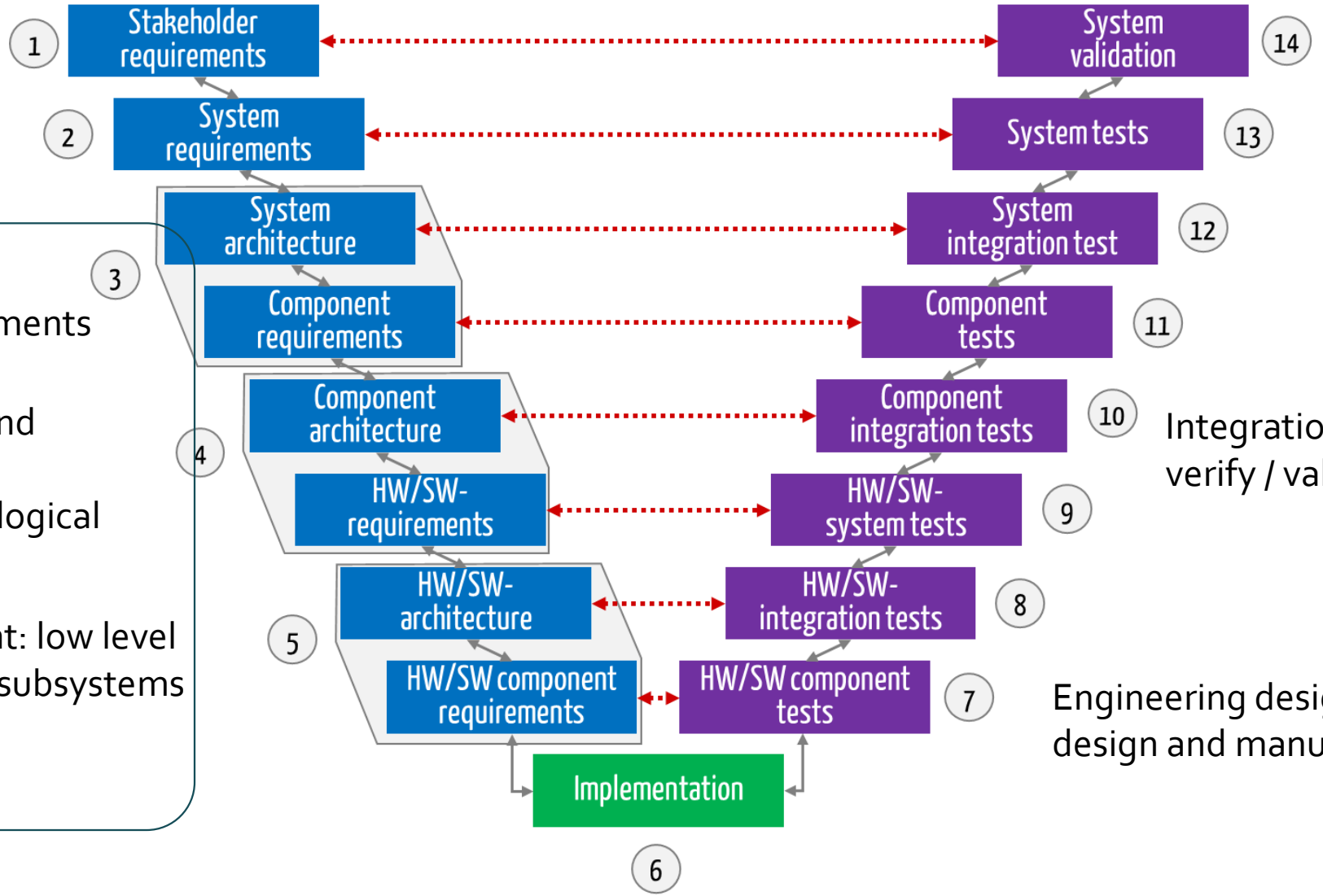
Functional Decomposition

System engineering: system level decisions



System Engineering: Development process….

Stakeholder needs:



Concept Exploration

Performance requirements

Functional Analysis and formulation:
Functional, physical, logical arch.

Detailed development: low level requirement / define subsystems configs

Integration and test: build and verify / validate system

Engineering design: detail design and manufacturing

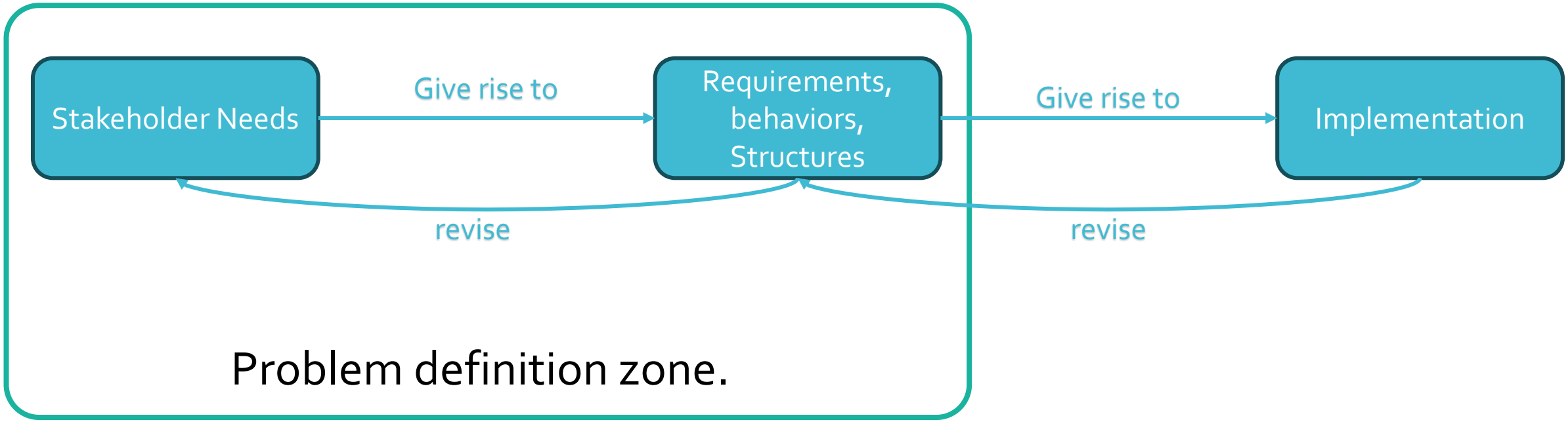
System Requirements and Verification

System requirements

- What requirements are?
- What makes a good requirement?
- How they contribute to the system design?

System requirements: What are SR?

SE Workflow /Processes

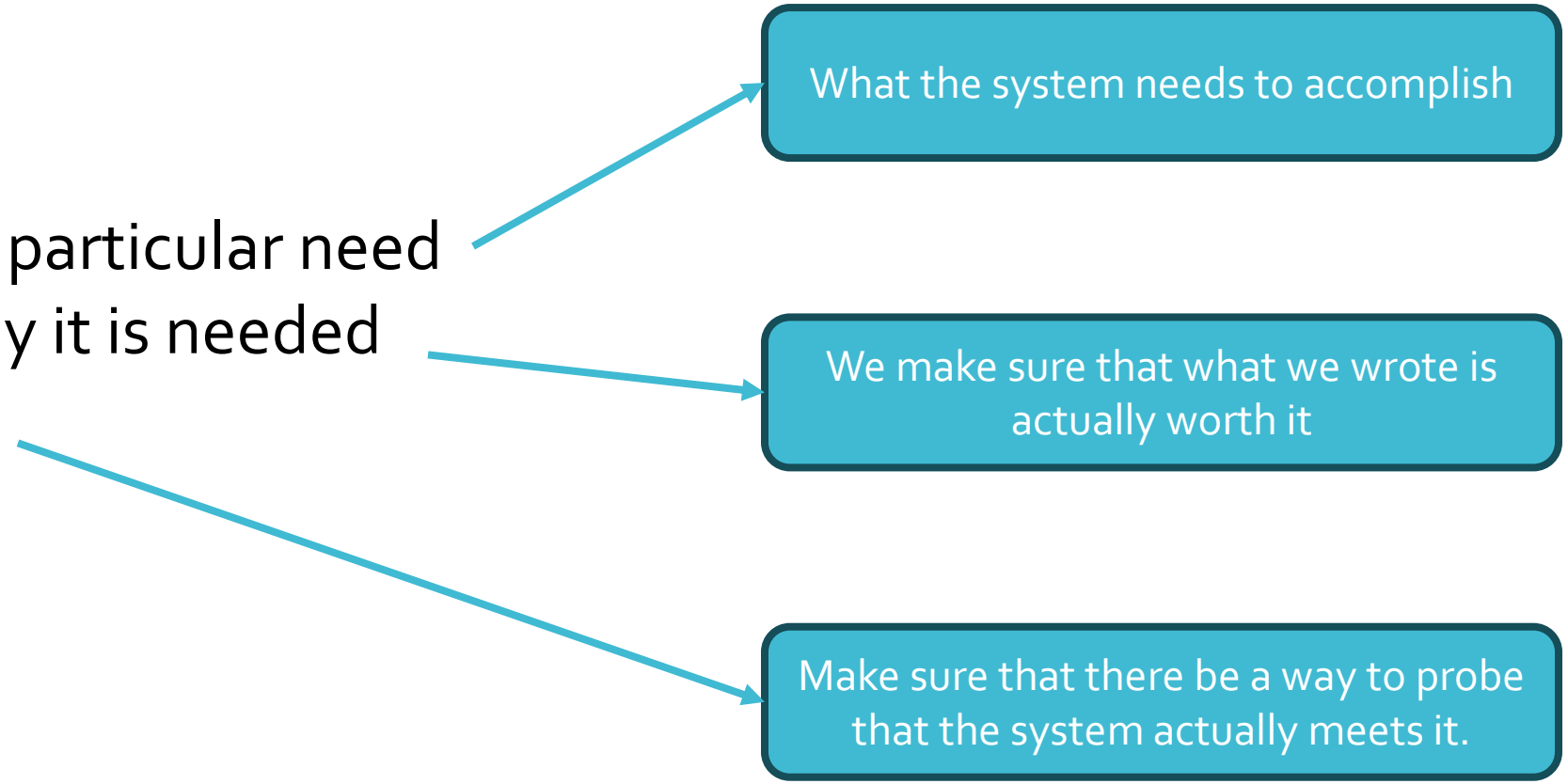


System requirements: what creates a requirement?

- A description of a particular need.
- A rationale for why it is needed.
- A way to verify it.

System requirements: what creates a requirement?

- A description of a particular need
- A rationale for why it is needed
- A way to verify it



System requirements: types of requirements

- **Functional**: which functions are needed?
- **Performance**: How well must it perform?
- **Constraint**: what are the limiting parameters?
- **Environmental**: what is the operational environment?
- **Reliability**: How reliable should it be?
- ….

System requirements: requirements examples

- **Functional**:
  The device **shall** regulate the output voltage to 5.0V +/- 10%.
- **Constraint**:
  The device **shall** not exceed 10uA of quiescent current in standby mode.
- **Environmental**:
  The device **shall** comply with the radiated emissions limits specified in CISPR 22 Class B for the frequency range of 30 MHz to 1 GHz.

System requirements: requirements validity

- **Is the requirement valid?**

If so, what´s the rationale behind?

1) The requirement is something that we **"actually"** want in the system.
2) It must convey the right message.

System requirements: requirements validity

- **Is the requirement valid? If so, what´s the rationale behind?**

1) The requirement is something that we sold in the system

There must be a way to relate these requirements to the stakeholder needs:

- The voltage regulator will be sold in Europe, therefore must comply with local EMC regulation

VALID

Doesn't trace back to the stakeholder
Probably inconsistent with other requirements

- The device shall regulate the output voltage to 5.0V +/- 0.01%.

INVALID

Two individual reqs. could appear as valid even traceable to the stakeholder needs but might be inconsistent between them

System requirements: requirements validity

- **Is the requirement valid? If so, what´s the rationale behind?**

2. It must convey the right message: the requirement must be clear, concise and unambiguous.

Avoid using words like "minimize" / "maximize".

The device shall not exceed 10uA of quiescent current in standby mode.	VALID
Minimize the power consumption of the device while in standby	INVALID

System requirements: requirements validity

- **Is the requirement valid? If so, what´s the rationale behind?**

2. It must convey the right message: the requirement shouldn´t specify implementation.

They describe WHAT and not HOW it should be done.

- The device shall regulate the output voltage to 5.0V +/- 10%.

VALID

The device should use a voltage divider to regulate the output voltage.

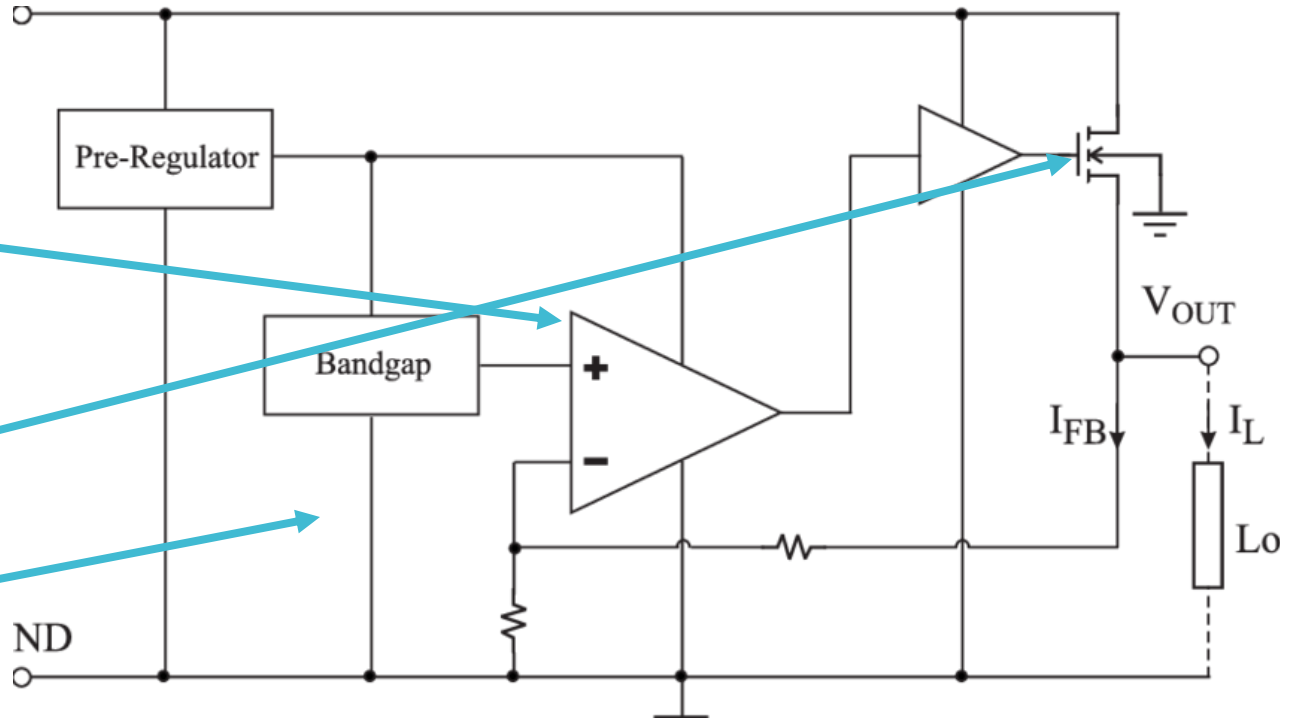
INVALID

Side note: There might be singular situationts that a requirement specifies an implementation. For example for regulatory aspects.

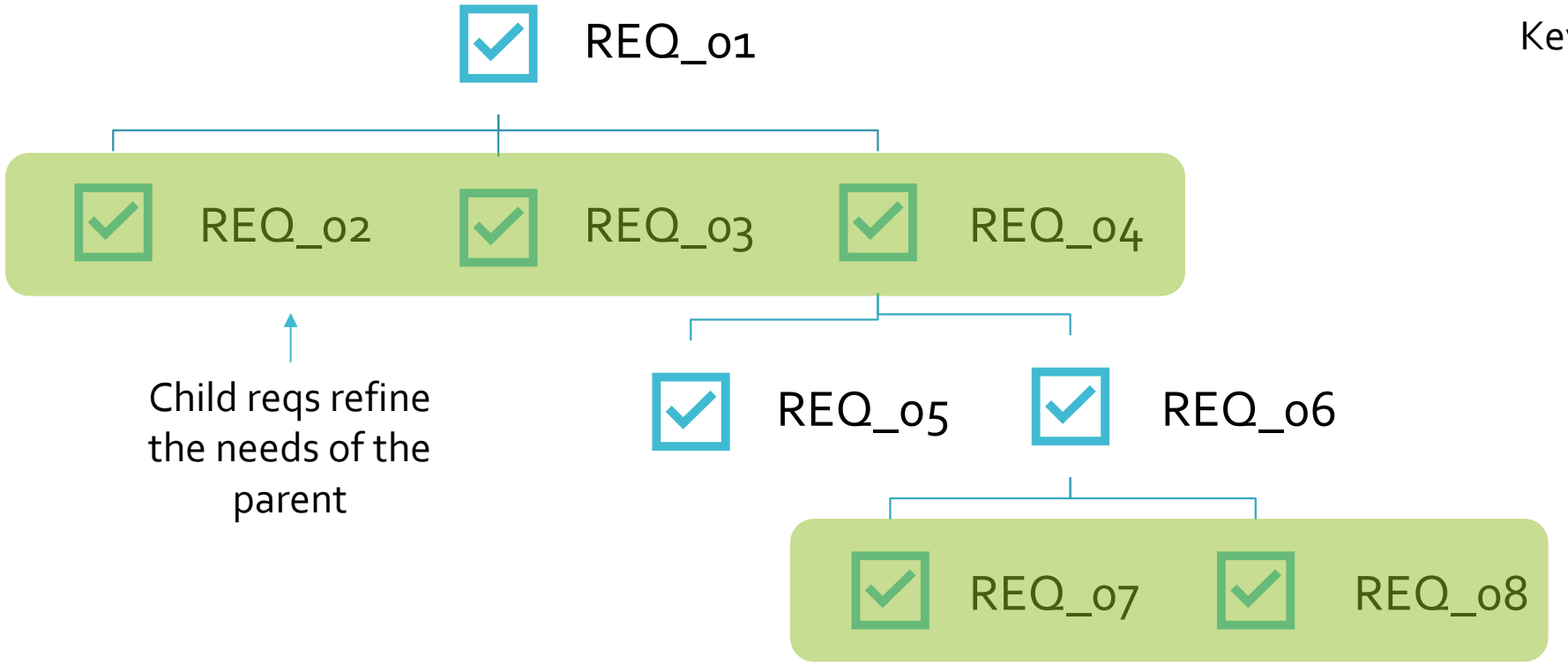
Allocation, verification and validation

System requirements: requirement allocation

REQ_ID	Description
REQ01	The device shall regulate the output voltage to 5.0V +/- 10%.
REQ02	The device shall whitstand a load of 100mA
REQ03	The device shall not exceed 10uA of quiescent current in standby mode.



System requirements: requirement hierarchy



Key Programatic Requirements

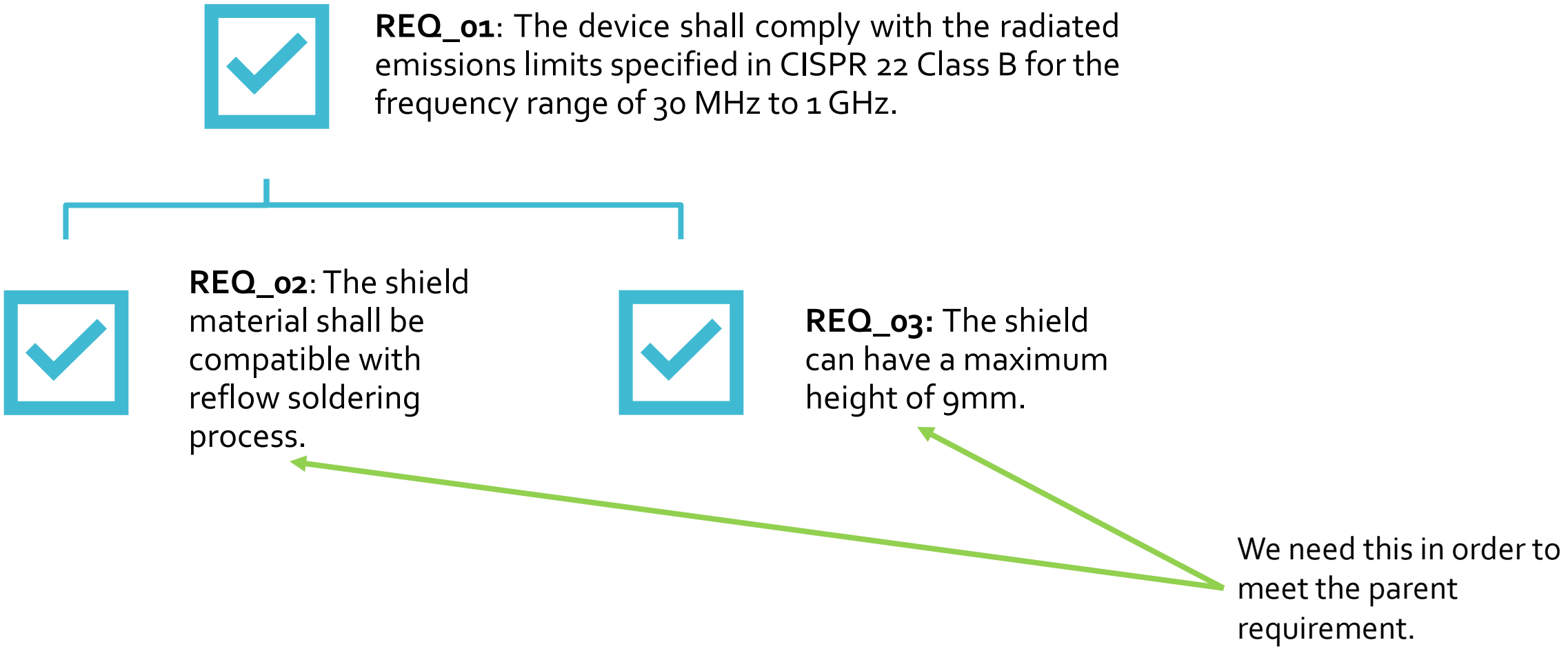
Functional

System

Sub Systems

Its hard to decompose requirement to a lower level and staying solution neutral

System requirements: requirement hierarchy



System requirements: requirement hierarchy

REQ_01: The device shall comply with the radiated emissions limits specified in CISPR 25 for the frequency range of 150 kHz to 2.5 GHz.

REQ_02: The shield material shall be compatible with reflow soldering process.

REQ_03: The shield can have a maximum height of 9mm.

- Complete?
- Consistent?
- Necessary?

System requirements: verification coverage

REQ_01: The device shall comply with the radiated emissions limits specified in CISPR 25 for the frequency range of 150 kHz to 2.5 GHz.

TC_01: Validation round at EMC lab

REQ_02: The shield material shall be compatible with reflow soldering process.

TC_02: DoE in reflow oven.

REQ_03: The shield can have a maximum height of 9mm.

TC_03: Mechanical interference

Requirements Traceability Matrix (RTM)

Requirement ID	Requirement Description	Design	Development	Testing	Test ID	Deployment
RQ1	User registration functionality	Yes	In-Progress	Yet To Start	T001	
RQ2	Product search and filtering capabilities	Yes	Completed	In-Progress	T002	
RQ3	Add to cart functionality	Yes	Completed	Completed	T003	In-Progress
RQ4	Payment integration with third-party API	In-Progress	Yet To Start	Yet To Start	T004	
RQ5	Order confirmation email notification	Yes	In-Progress	In-Progress	T005	

System requirements: verification coverage

REQ_01: The device shall comply with the radiated emissions limits specified in CISPR 25 for the frequency range of 150 kHz to 2.5 GHz.

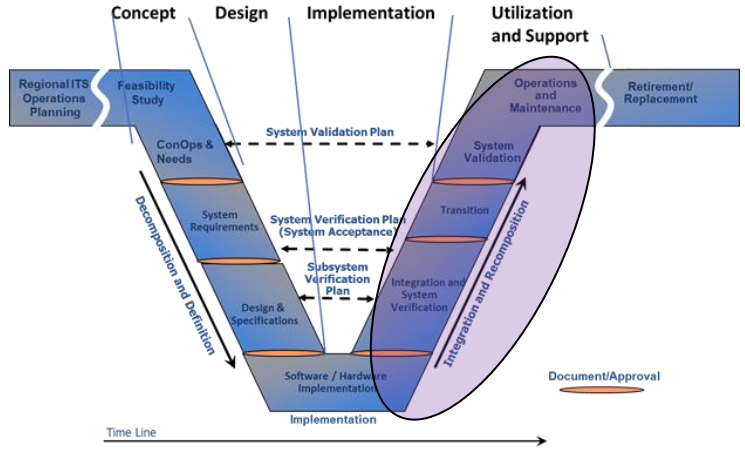
TC_01: Validation round at EMC lab

REQ_02: The shield material shall be compatible with reflow soldering process.

TC_02: DoE in reflow oven.

REQ_03: The shield can have a maximum height of 9mm.

TC_03: Mechanical interference



Wrap Up

Wrap Up

- We explored the Systems Engineering (SE) discipline and the pivotal role of the Systems Engineer.
- We examined the utility of Model-Based Systems Engineering (MBSE) in managing the complexities of medium to large-scale projects.
- We understand the process of decomposing high-level needs into specific, testable requirements and constraints.
- We elaborate how these requirements are allocated to different architectural blocks or subsystems within the overall system.
- We verification and validation processes, emphasizing the use of dedicated test cases to ensure that each requirement is met and the system functions as intended.

References.

- Matlab Tech Talk: Systems Engineering, Parts 1 to 4
- INTERNATIONAL COUNCIL ON SYSTEMS ENGINEERING: https://www.incose.org/

Until next Friday…