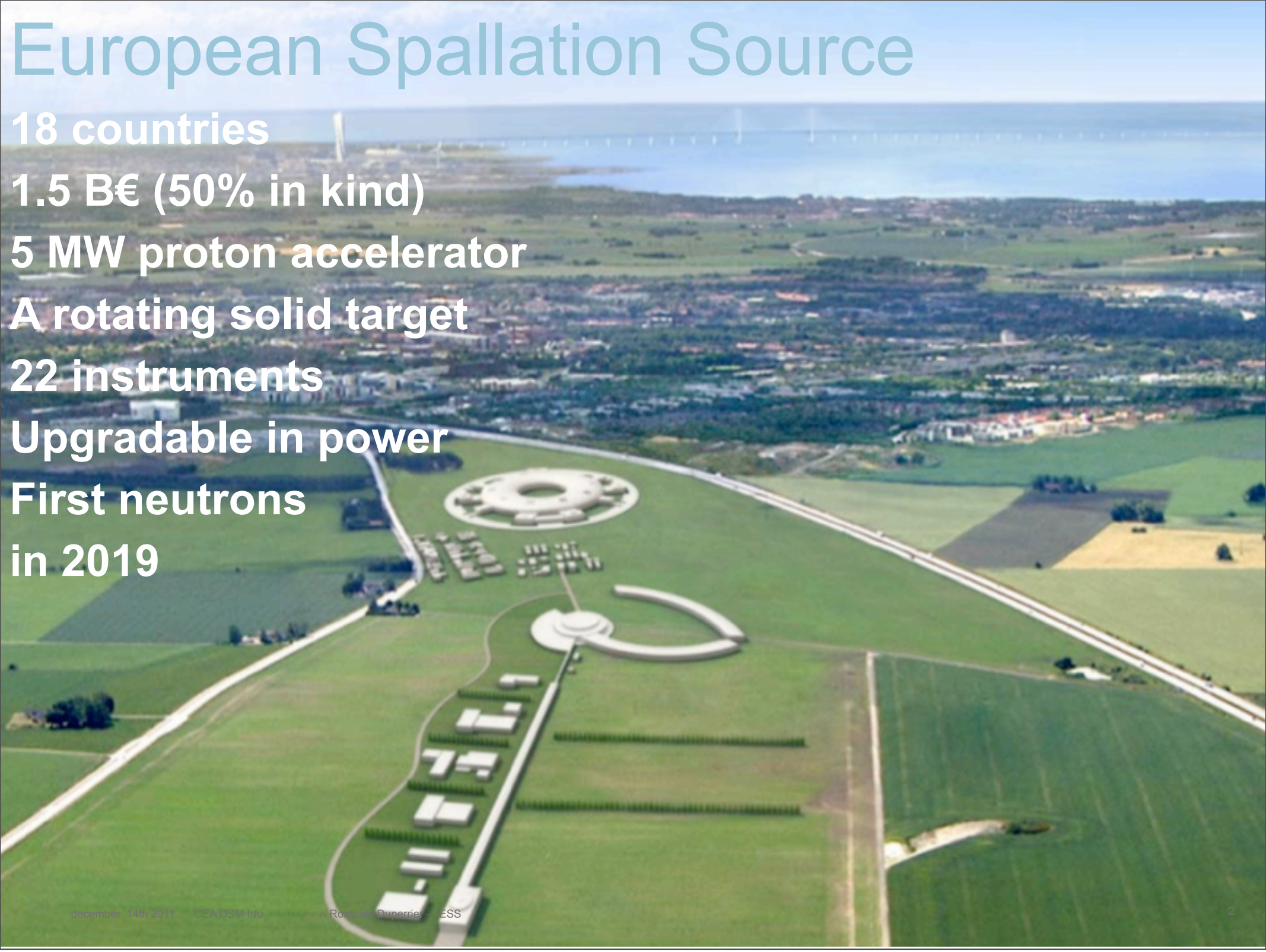
Towards ESS prototyping and construction

EUROPEAN SPALLATION SOURCE

Romuald Duperrier - CEA /Saclay

System Engineer

European Spallation Source



18 countries

1.5 B€ (50% in kind)

5 MW proton accelerator

A rotating solid target

22 instruments

Upgradable in power

First neutrons

in 2019

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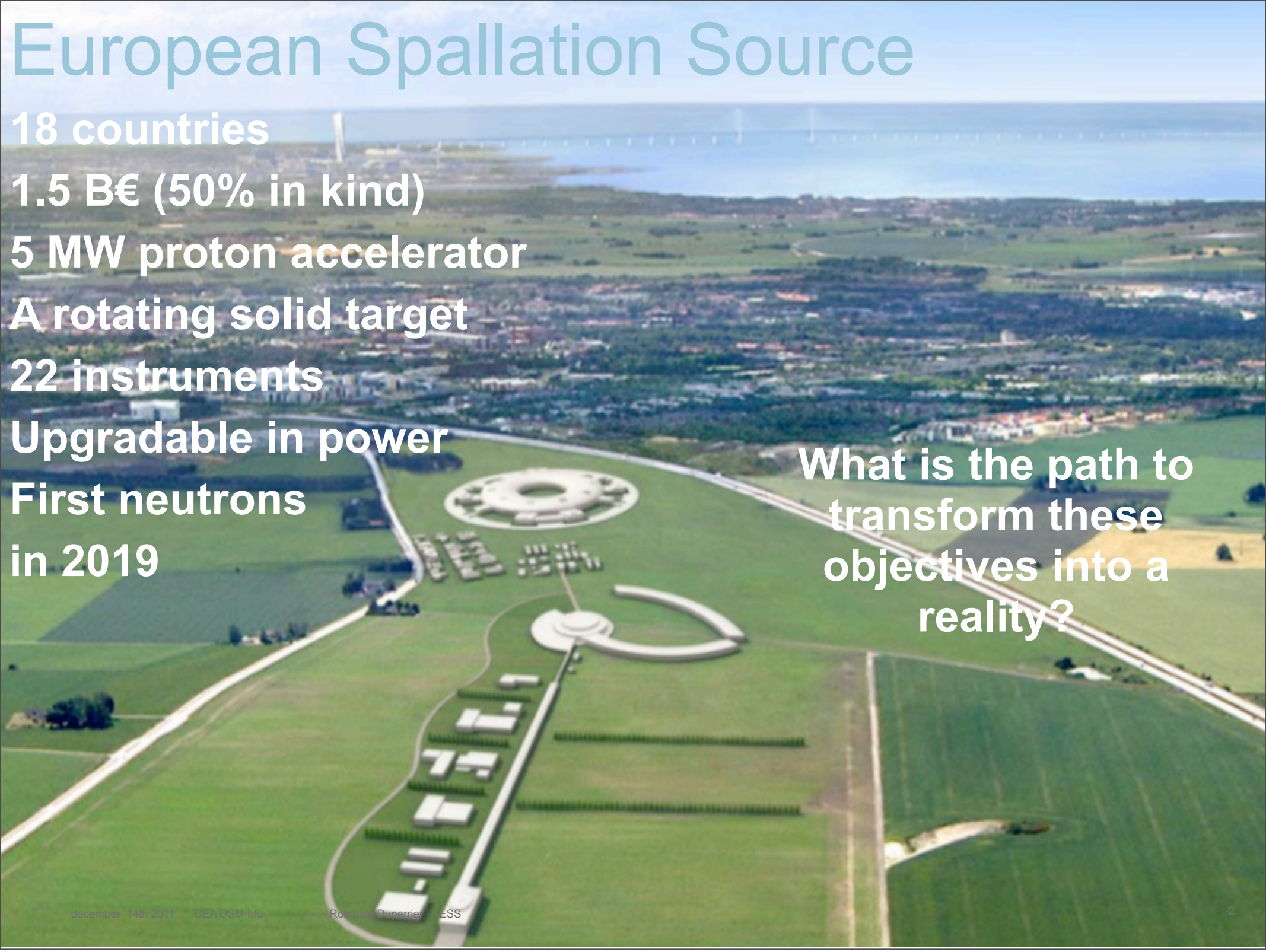


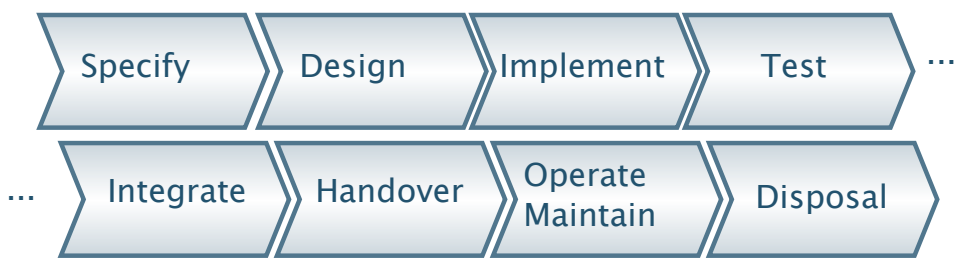
What is the path to transform these objectives into a reality?

Building large facilities:3 key dimensions

Organizations (who)

Products (what)

Processes (how)



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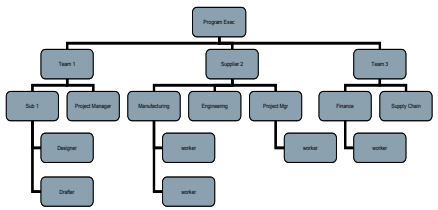

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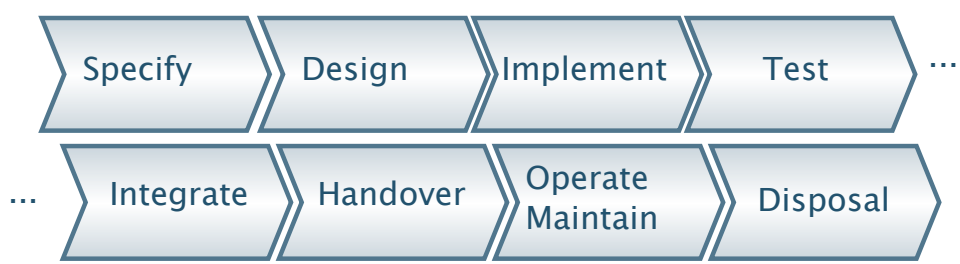

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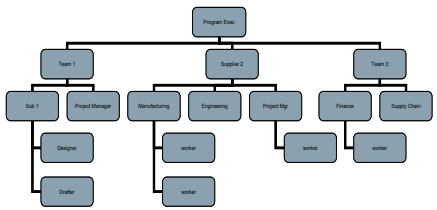

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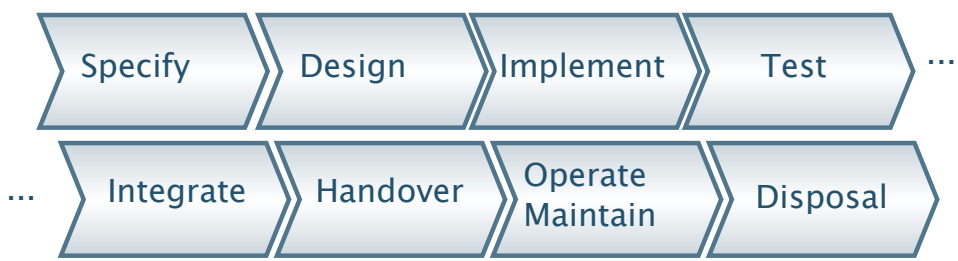

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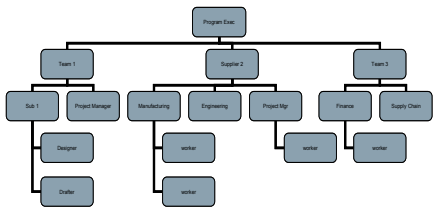

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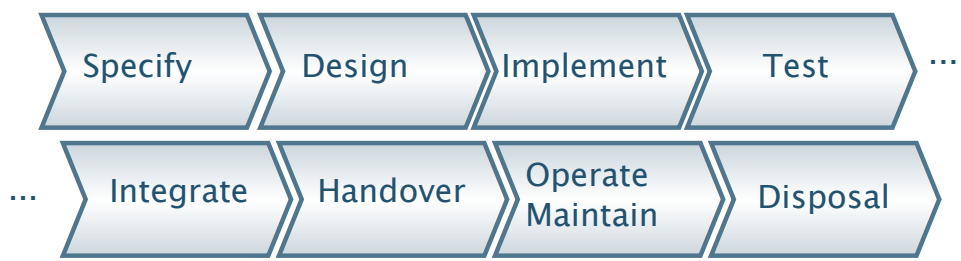

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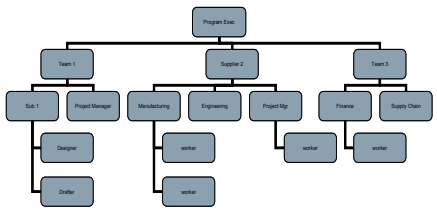

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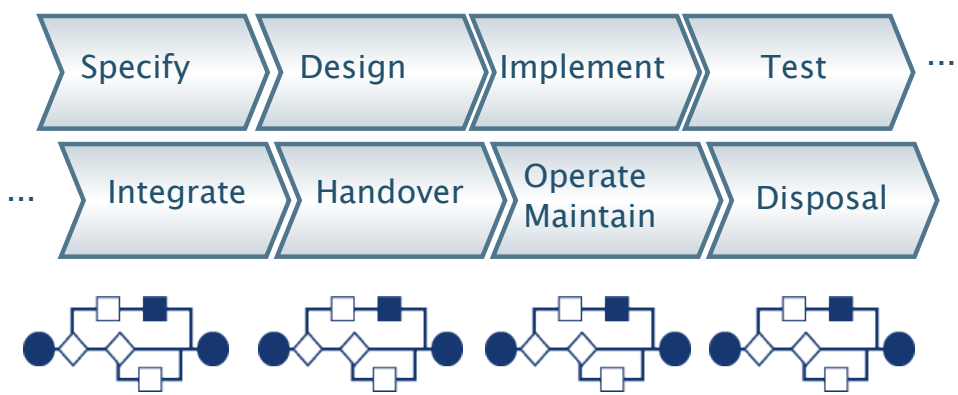
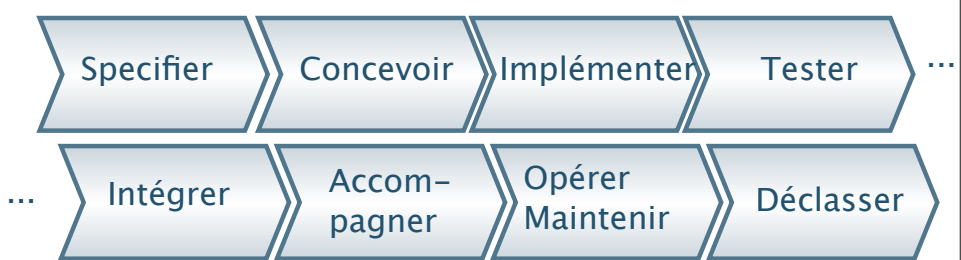


Building large facilities:3 key dimensions

Organisations (qui)

Produits (quoi)

Processus (comment)



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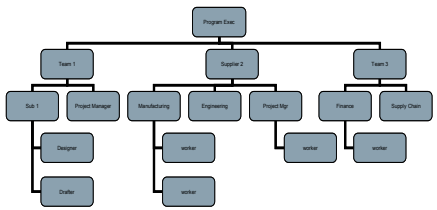

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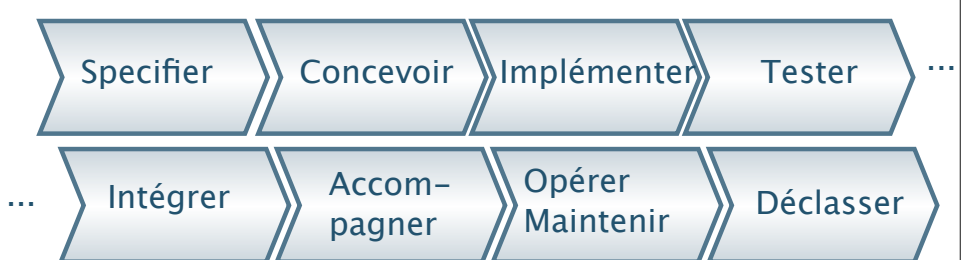

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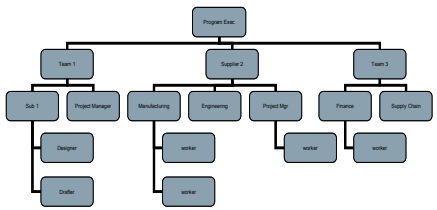

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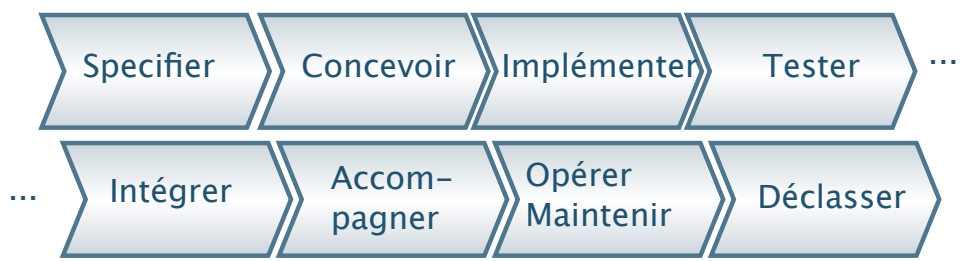

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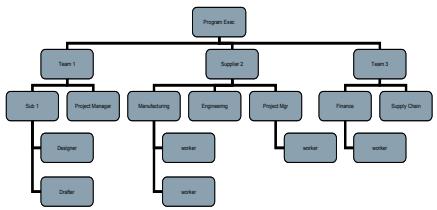

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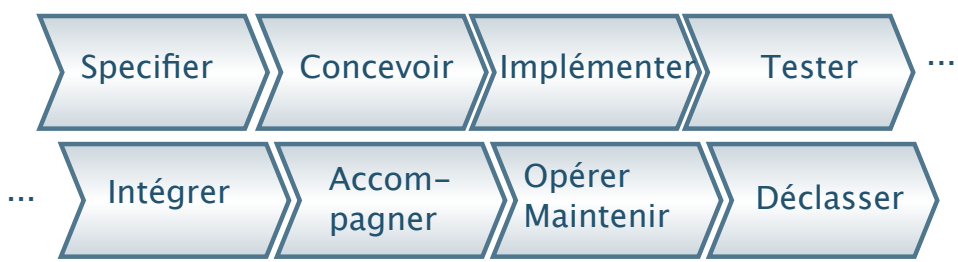

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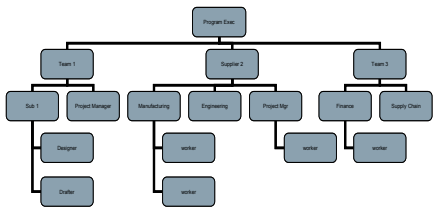

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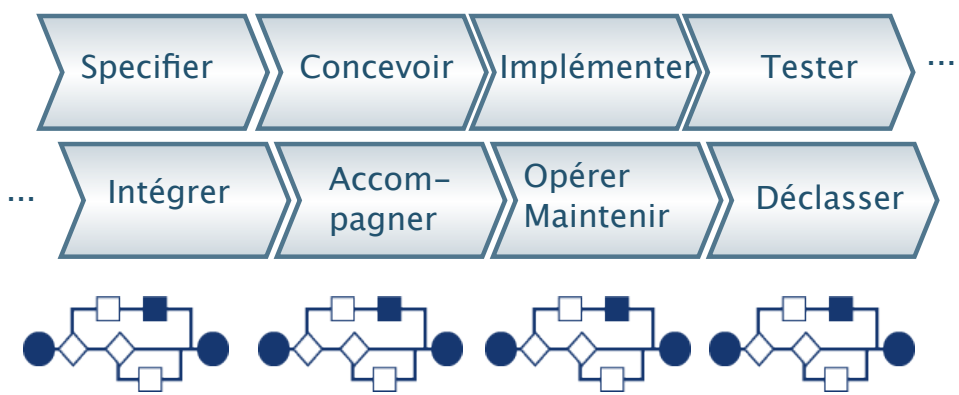
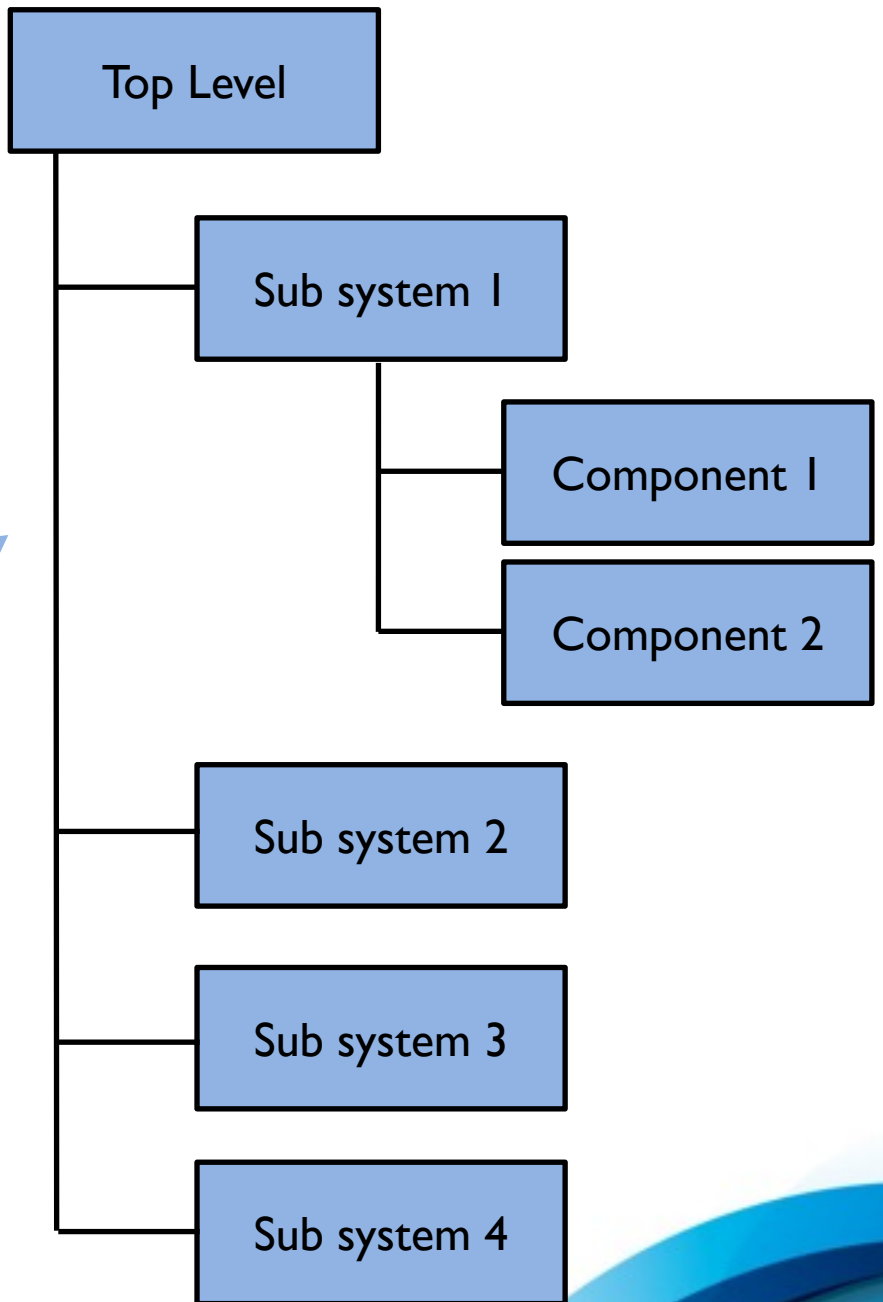


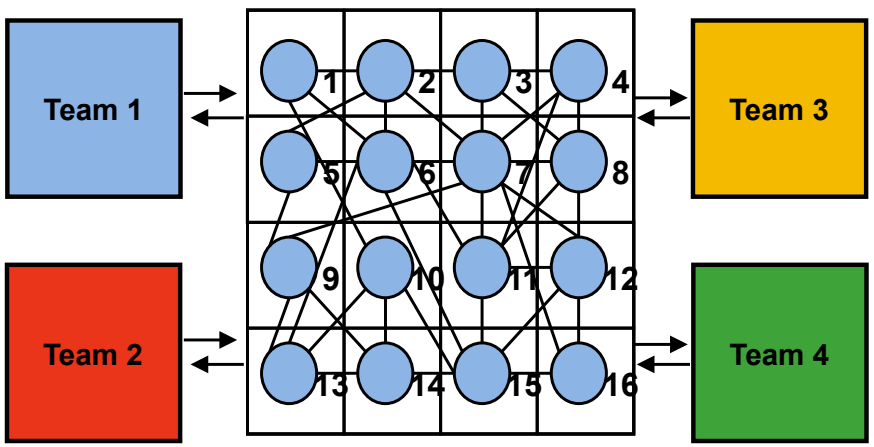
Identify the subsystems and interfaces



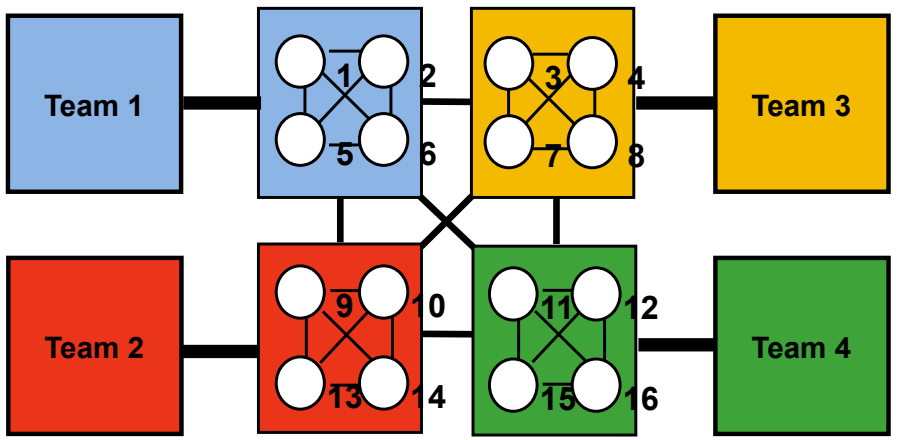
Products (what)

System design and collaborations

Integral architecture



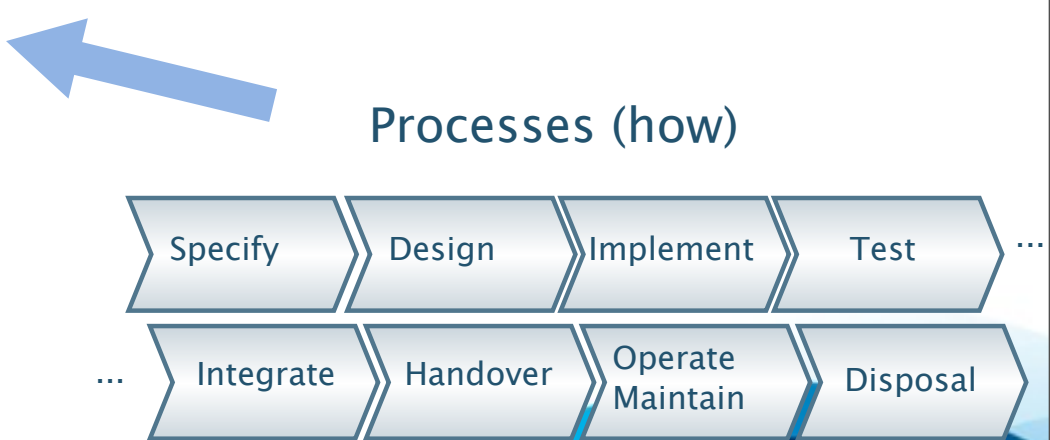
Modular architecture



Products (what)

Often a combination of both

The waterfall process model



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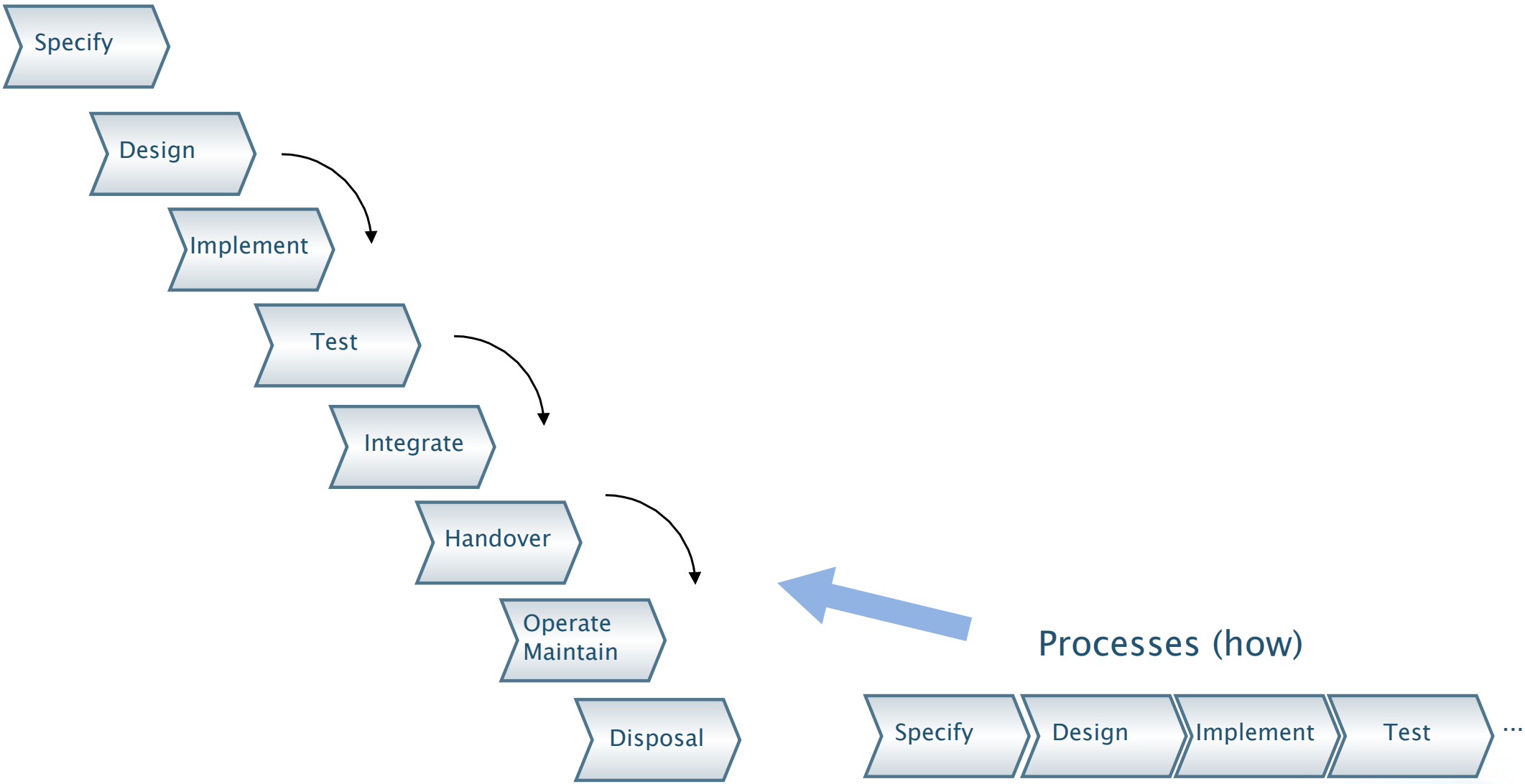

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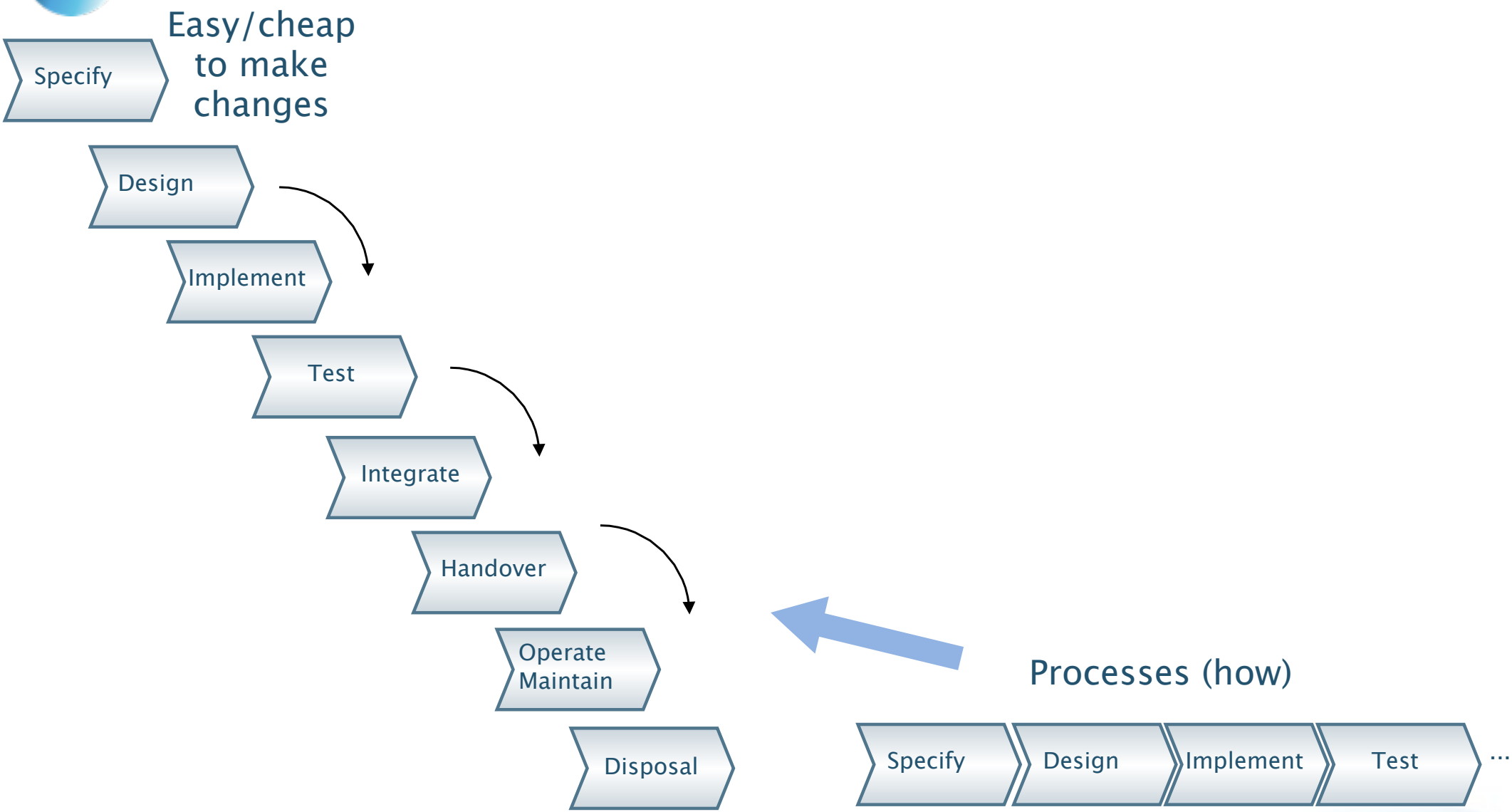

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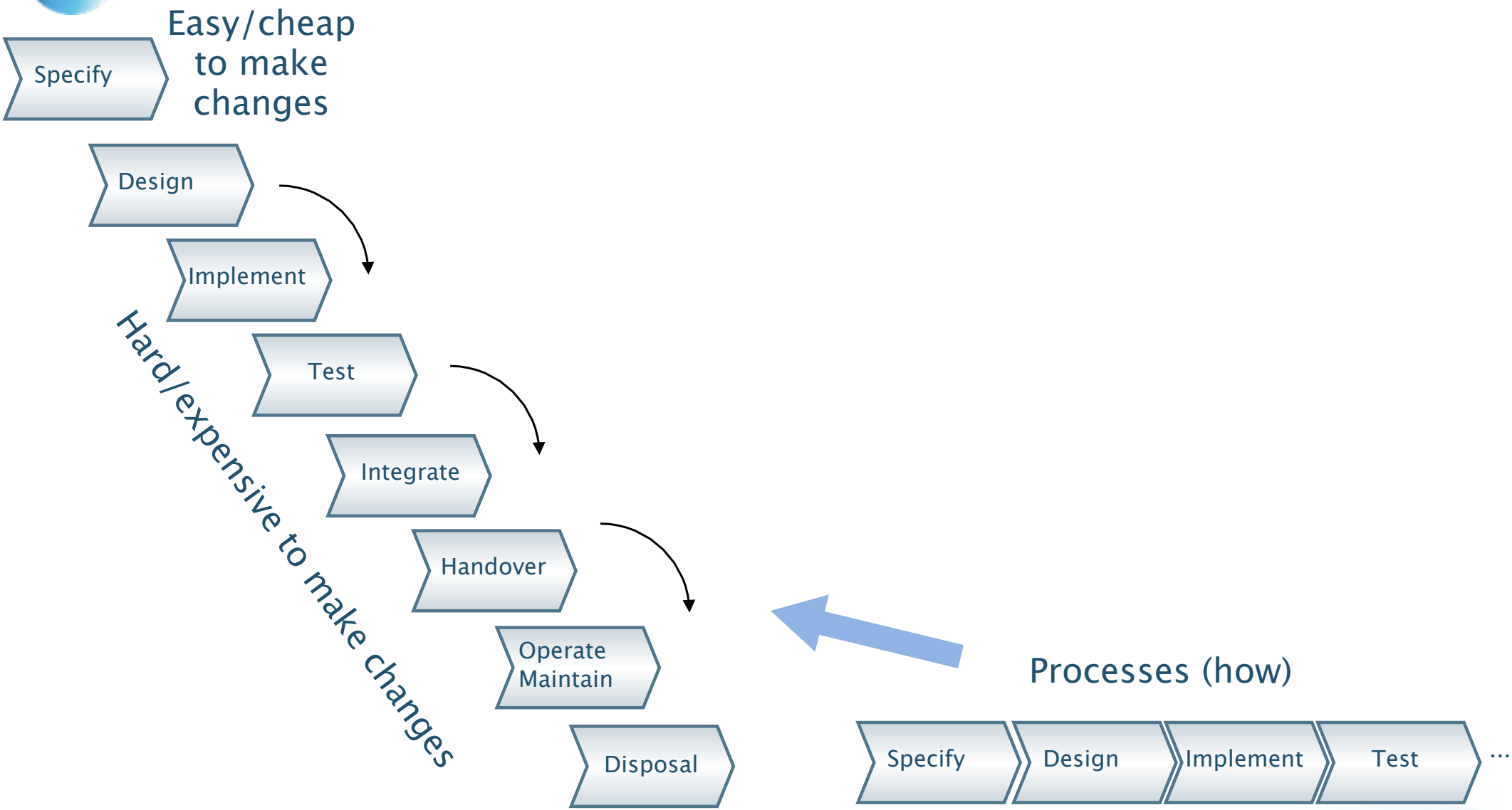


The waterfall process model

Easy/cheap to make changes

Specify

Design

Implement

Test

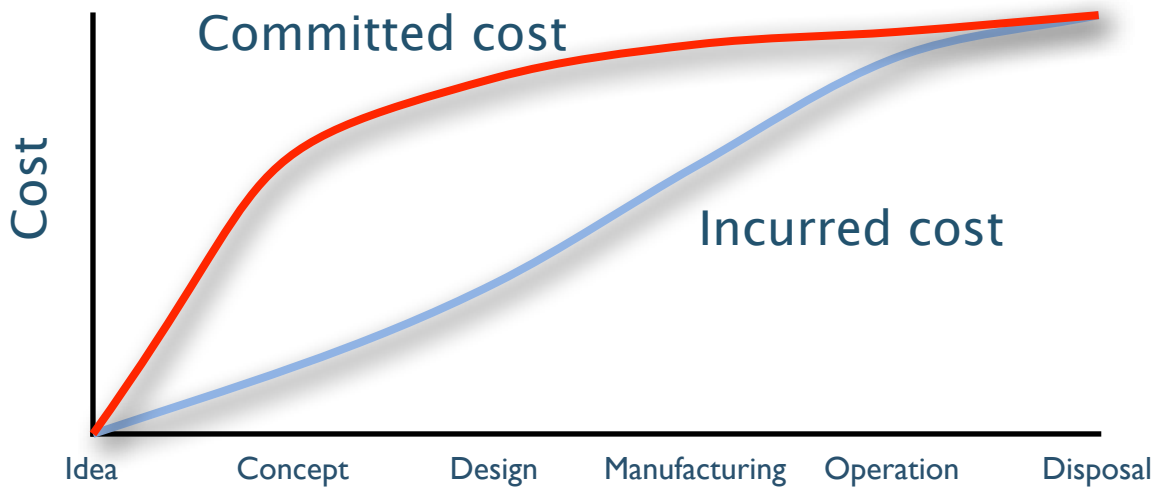
Integrate

Handover

Operate Maintain

Disposal

Hard/expensive to make changes

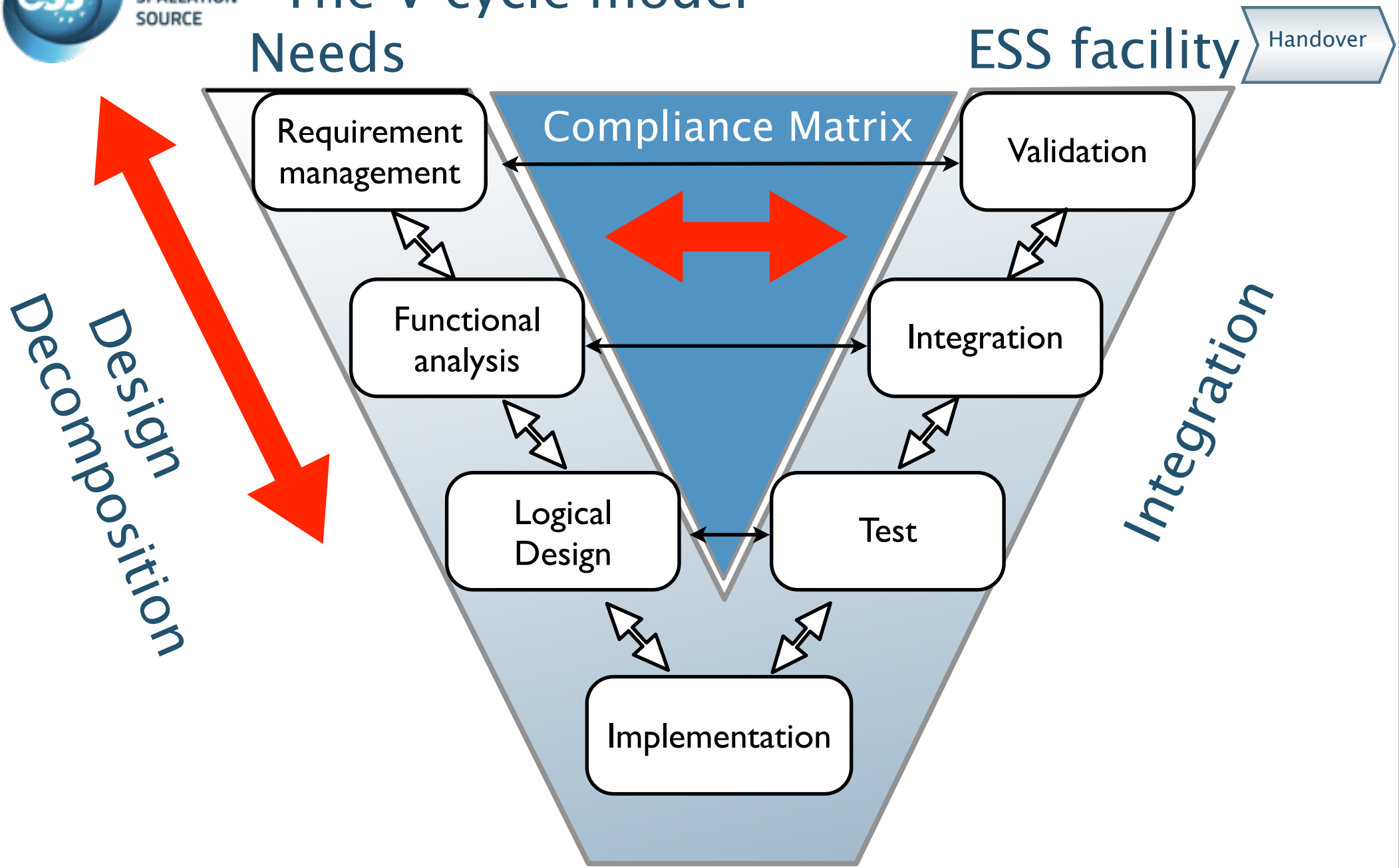


Processes (how)

Specify | Design | Implement | Test | ...

... | Integrate | Handover | Operate Maintain | Disposal

The V cycle model



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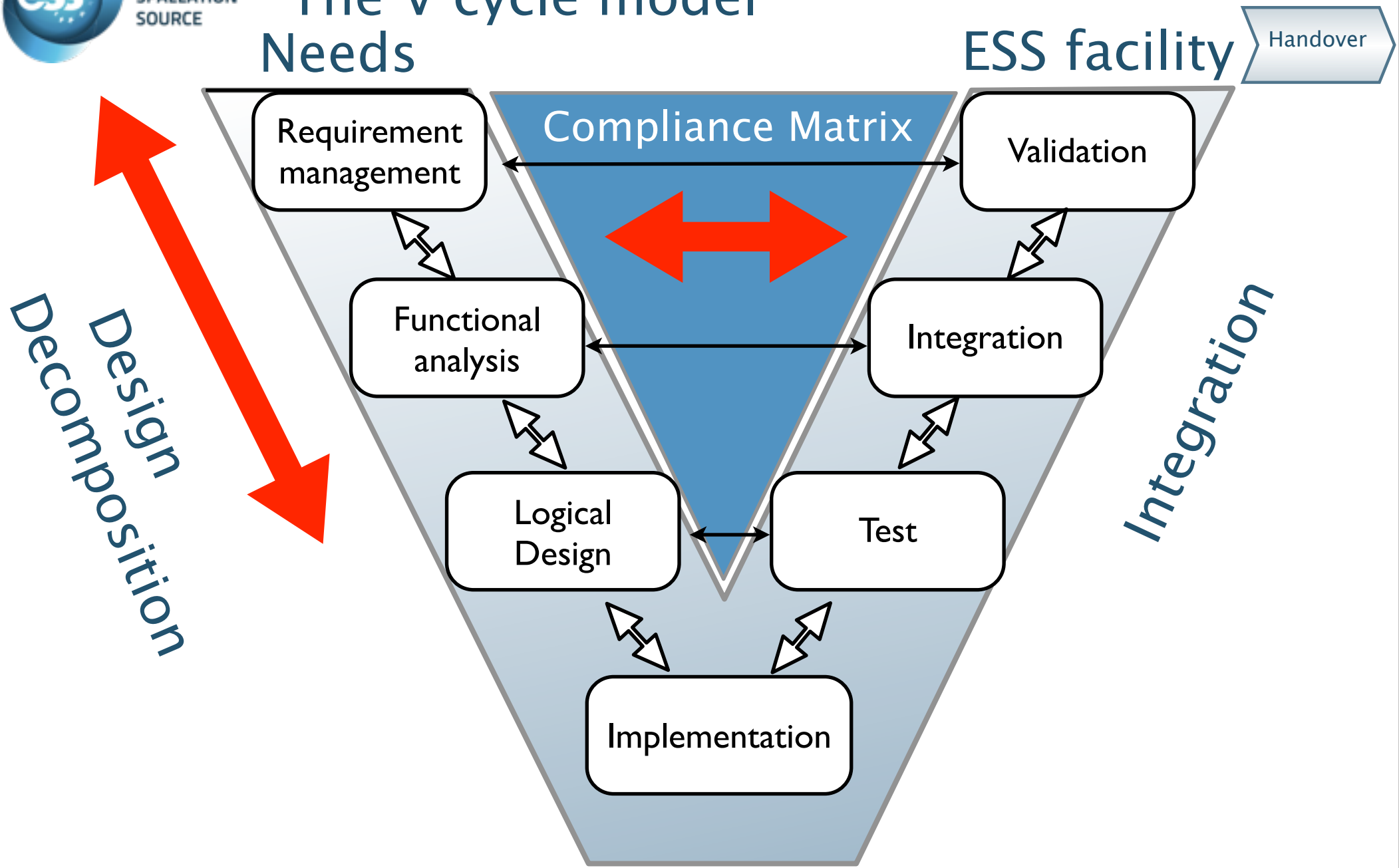

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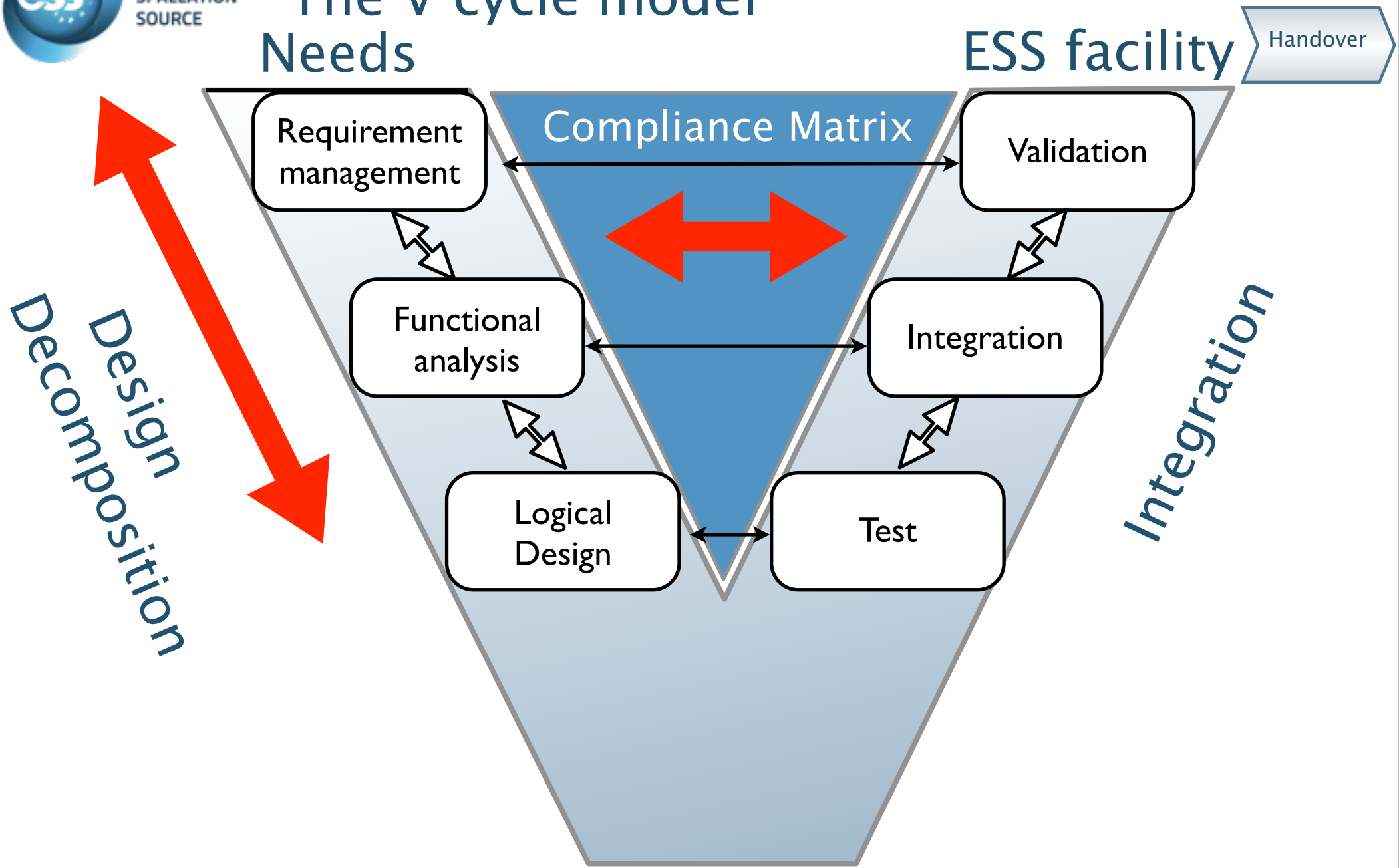

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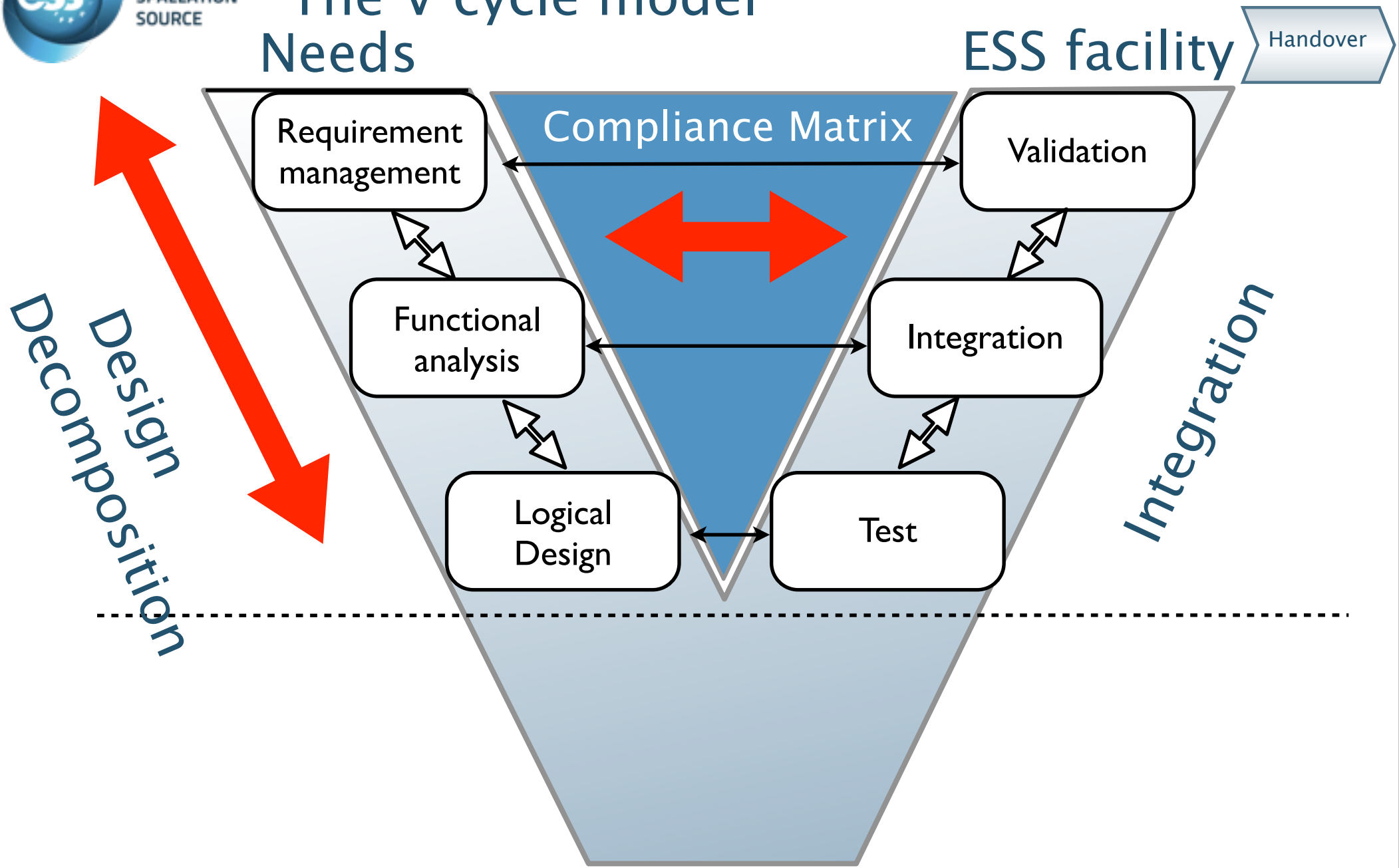

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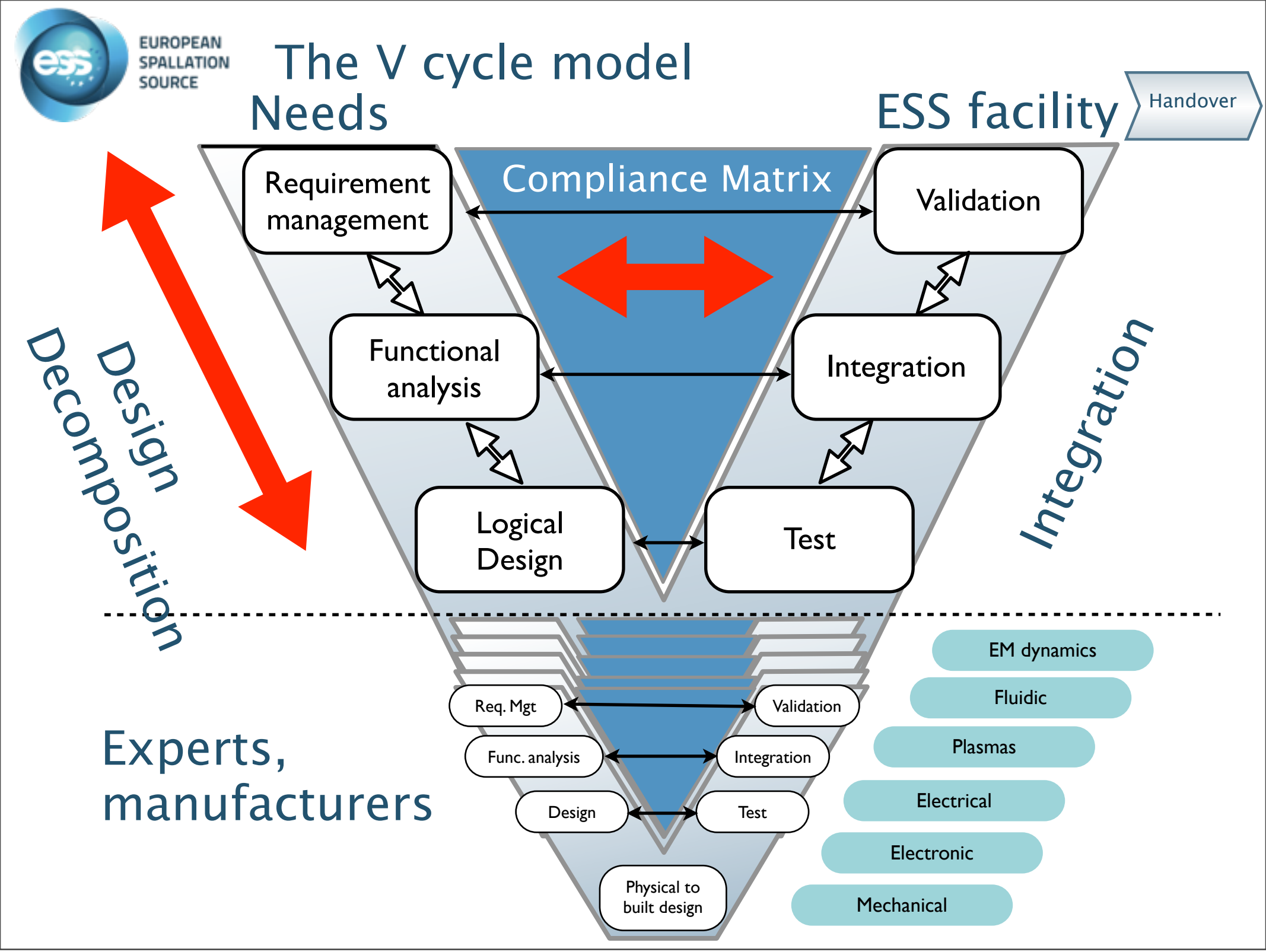

Baseline Process to get to design

- State Problem
- Define requirements
- Generate potential solutions
- Define sub-systems
- Flow down requirements to sub-systems
- Evaluate solutions at sub-system level
- Evaluate solutions at system level
- Pick preliminary design
- Iterate as needed

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State the problem

- This often comes from the customer (users, funding agencies),
- Make sure you understand the customer's needs.
- Make sure you understand what the customer wants.
- **Always, always, always state the problem and not the solution!**

Define requirements

- When the requirements are finished, any system that meets them should adequately address the customers problem.
- Making assumption can be dangerous.
- Make sure that all phases of the life cycle are addressed
- All systems should have their requirements documented with revision control.
- Traceability is mandatory.

Receipe for good requirements

- Each requirement is necessary
- Each should be unique (maybe)
- Identify owner
- Traceable
- Quantitative (gradual or binary)
- Verifiable!
- Approved
- Complete
- Make state conditions clear
- State any assumptions
- Avoid optimize, maximize or minimize
- Life cycle
- State units (i.e. Mars Climate Orbiter)

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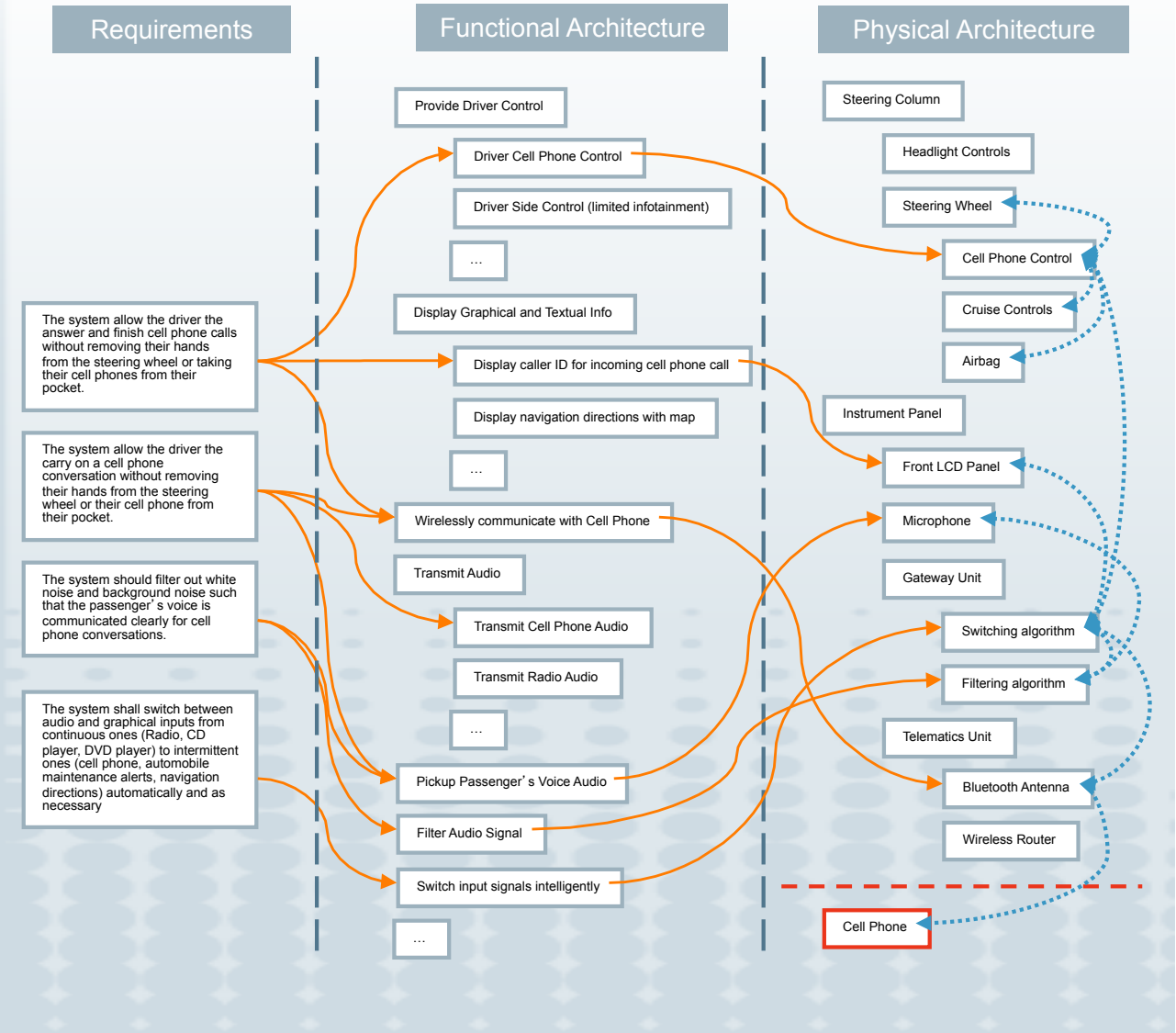
Verification

- Inspection.
- Demonstration.
- Analysis.
- Test.
- Certification.
- Similarity.
- Review.

Traceability



[M. Field, Frontiers 2008]

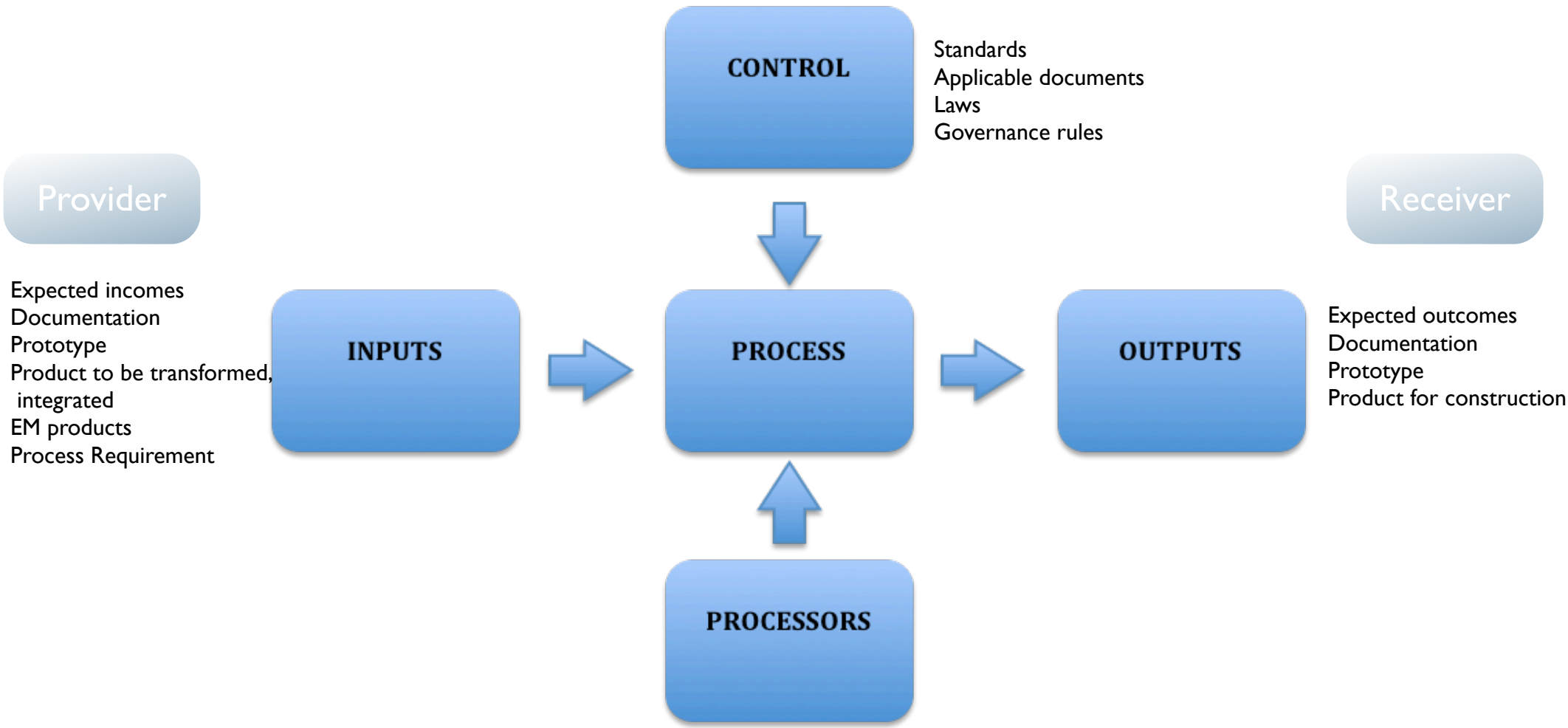
Design: define sub-systems

- Usually broken down by technical disciplines or system functions.
- One of the tasks of the systems engineers is to give well defined tasks to individuals or teams that can be worked on independently.
- Try to have clean boundaries between sub-systems.
- For big programs, there will be formal Interface Control Documents (ICD) between sub-systems
- The systems engineers get to make tradeoffs between different sub-systems.

Design: evaluate sub-systems

- Sub-system designs need to be compared to the requirements.
  - It should be the goals that determine which ones are better.
  - If all you have are requirements, then risk and cost usually are the deciding factors.

Process ingredients



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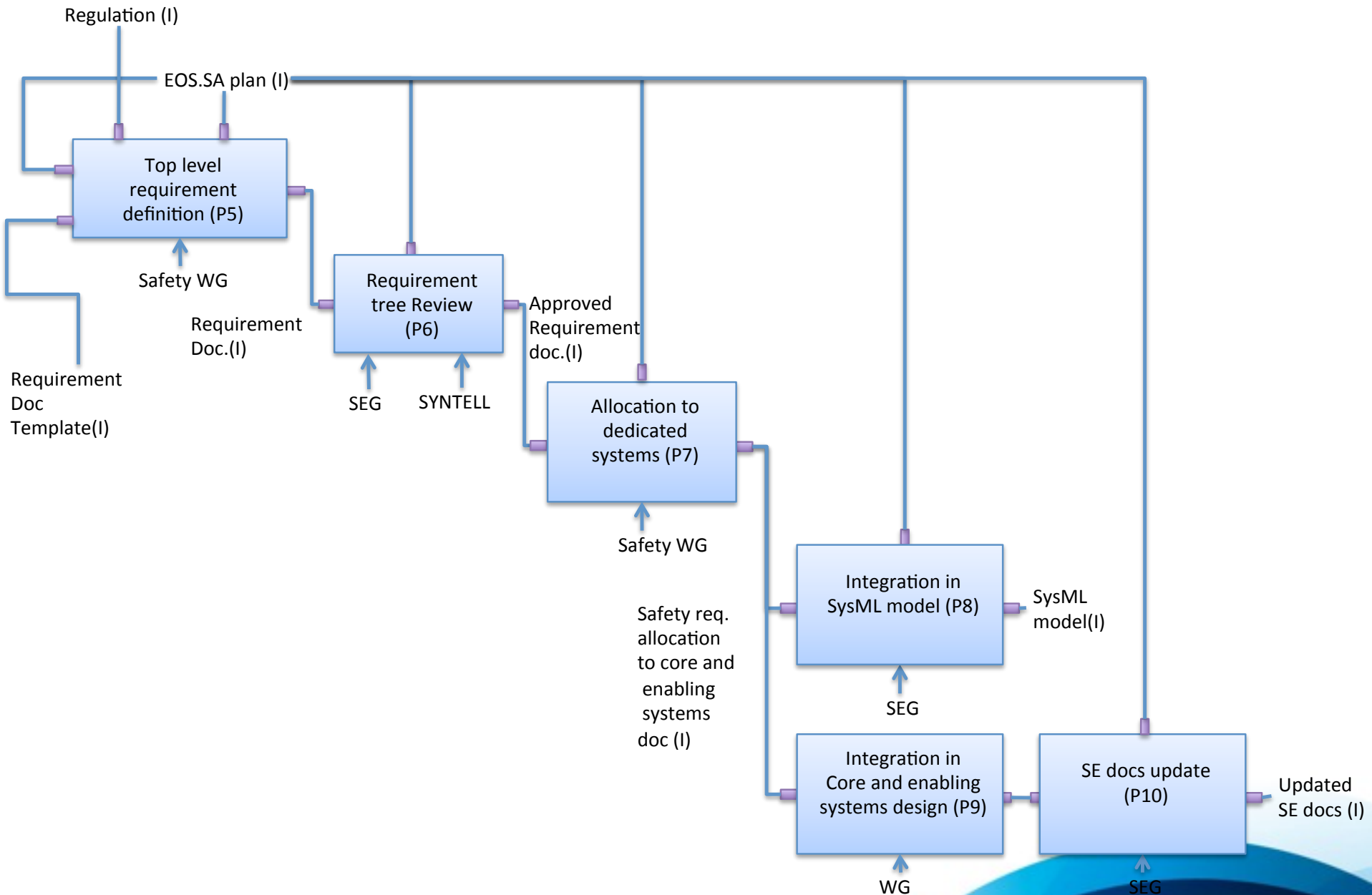
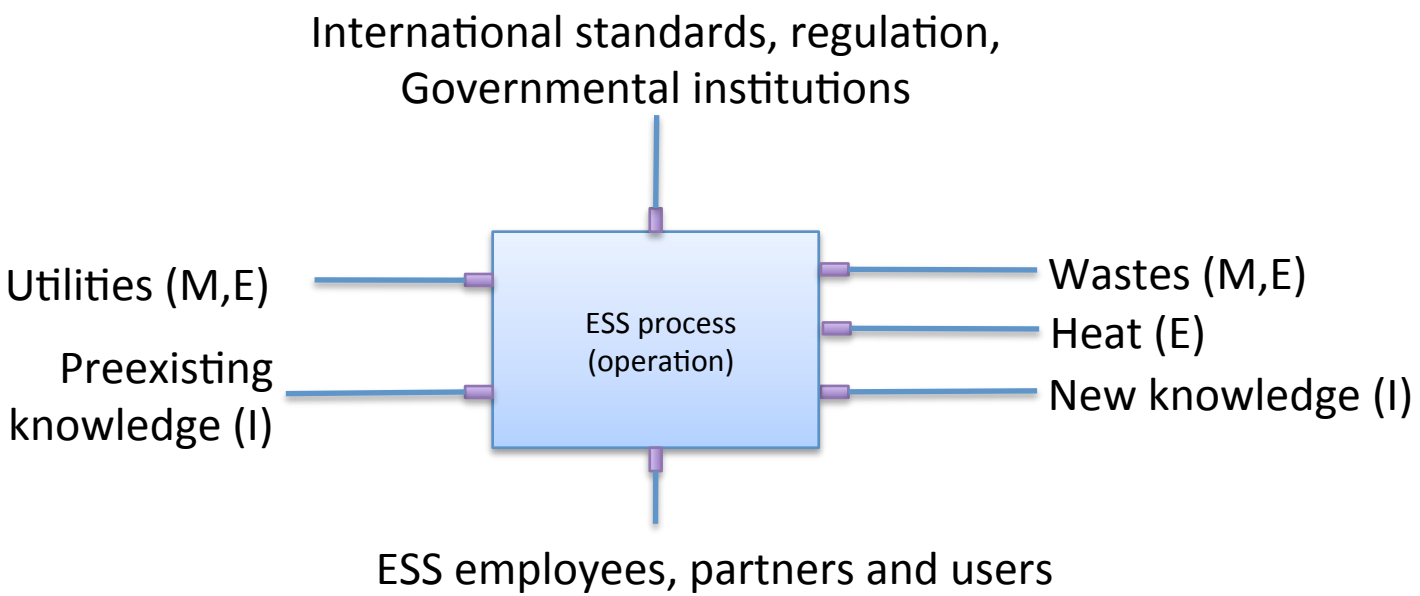
Process ID

Process name	
Purpose	*Goals of the process*
Scope	*System or field of interest covered by the process*
Tasks	*Tasks to be implemented*
Owner	*Stakeholder who has the responsibility for the performance of the process*
Client	*Recipient of the outputs*
Supplier	*Provider of the inputs*
Processor	*Responsible person for the implementation of the process*
Input	*Data and/or material to be processed*
Ouput	*Expected result of the process*
Control	*Procedures, standards, rules applicable for the implementation of the process*
Comments	
References	*Documents that are in line with the process*

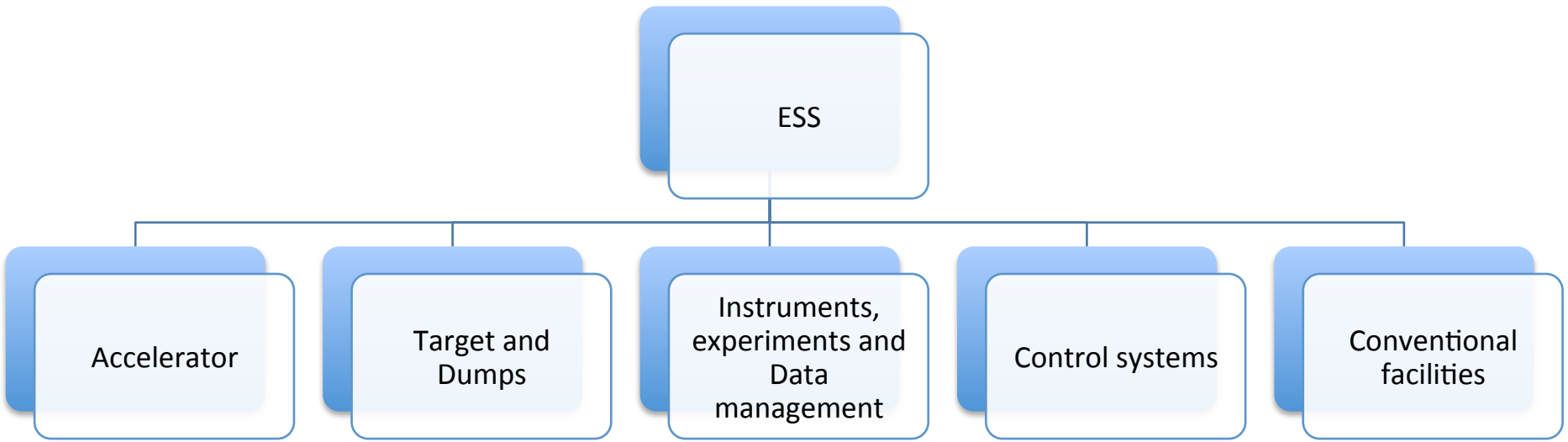
Workflow example



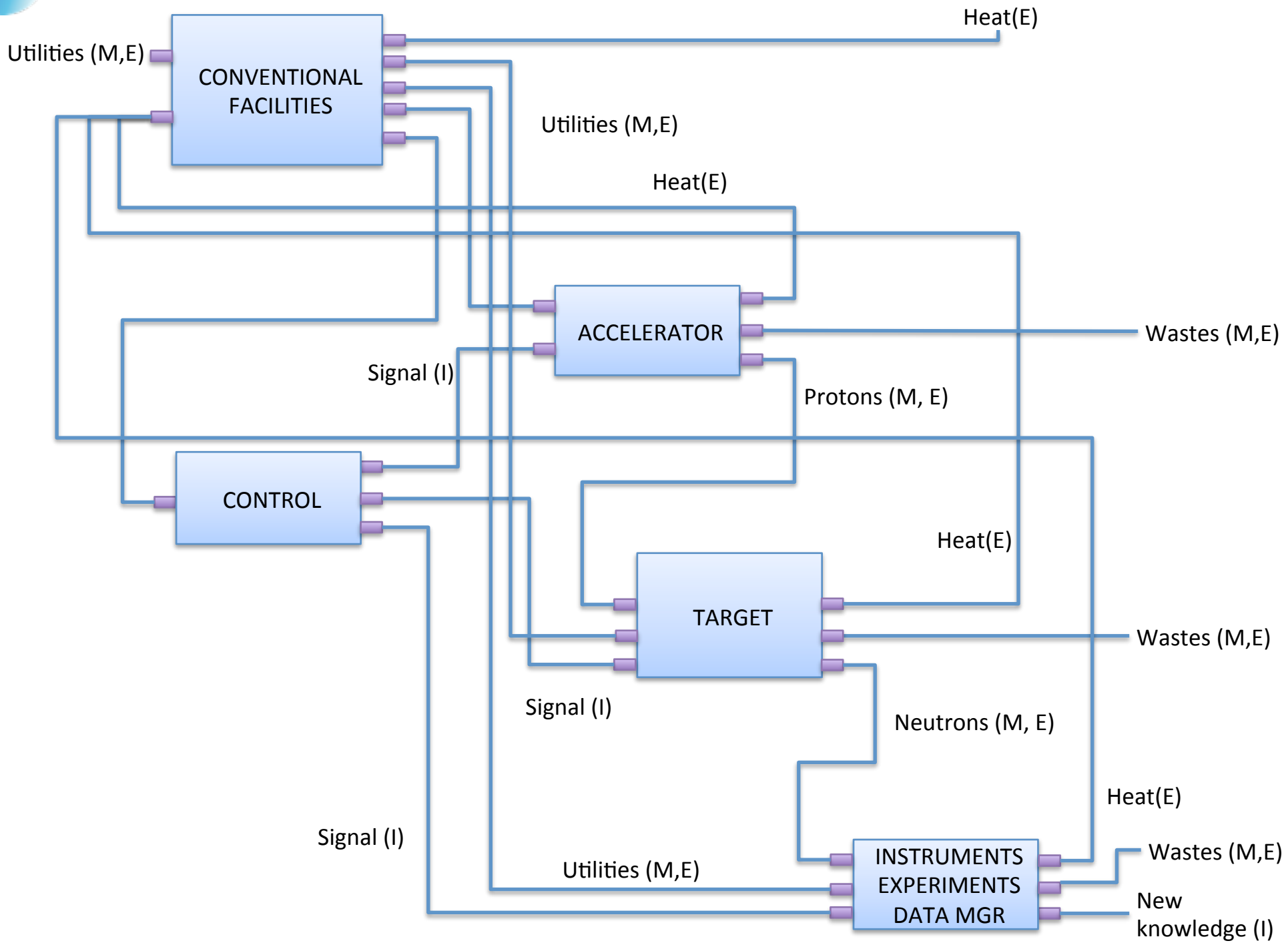
ESS case (draft): operation process



ESS case (draft): Architecture – level 1



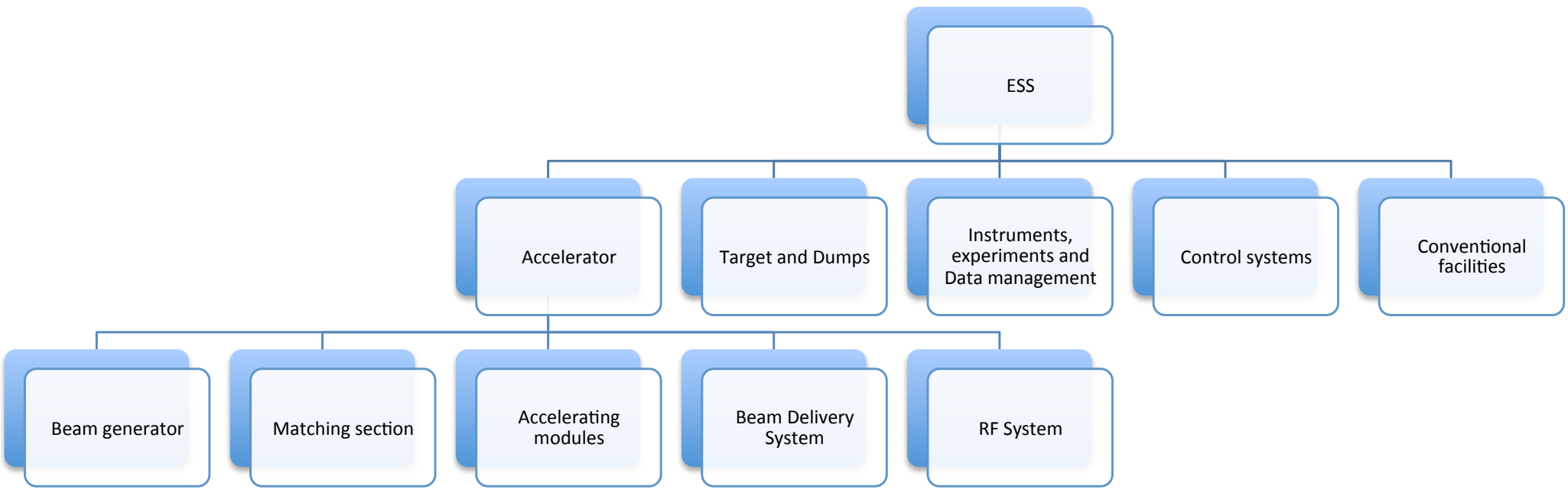
ESS case (draft): operation flows – level 1



Accelerator operation requirements (draft)

Long Name	Accelerator systems
Short Name	ACC
Stakeholders (actors)	Maintenance team, operators
Main Functions	1. Use matter and energy flows to generate, accelerate and deliver a pulsed proton beam either to the target or the dump. 2. Is remotely operationable. 3. Is power upgradable.
Performances	1. Beam power up to 5 MW 2. Beam Pulse length between 0,05 and 2,86 ± x ms 3. Beam repetition rate between 0,1 and 14 ± x Hz 4. Output peak proton current up to 50 ± x mA 5. Output beam energy = 2.5 + x – y GeV 6. Upgrade power up to 15 MW
Constraints	1. Conventional and radiation safety requirements 2. MTTR < x days. 3. MTTF > x days. 4. Lean development
Standards/ regulations	1. Norms and standards for the parts 2. Swedish regulation and laws

ESS case (draft): design – acc. level2



ESS RF systems requirements (draft)

Long Name	RF systems
Short Name	ACC.RFS
Stakeholders (actors)	Maintenance team, operators, designers
Main Functions	1. Use matter and energy flows to generate RF waves. 2. Transport RF waves through waveguides and resonators. 3. Maintain the stability of the amplitude and phase of the RF waves in resonators. 4. Is remotely operationable (amplitude and phase). 5. Is power upgradable.
Performances	1. Average Plug to beam efficiency 0,3. 2. Peak RF power transferred to beam up to 125 MW. 3. RF Pulse length between 0,4 and 3,2 ± x ms. 4. RF pulse repetition rate between 0,1 and 14 ± x Hz [TBC]. 5. Stability: phase ±1 deg, amplitude ±1% [TBC] 6. Upgrade peak power power transferred to beam up to 375 MW.
Constraints	1. Conventional and radiation safety requirements 2. Use 352,21 MHz and 704,42 MHz RF sources. 3. Use one RF source per SC cavity. 4. MTTR < x days. 5. MTTF > x days. 6. Lean development
Standards/ regulations	1. Norms and standards for the parts 2. Swedish regulation and laws

ESS RF systems verification (draft)

- The RF system coupled with the accelerator will involve an array of accelerating modules, each module being an array of equiped resonators (cavity, couplers, antenna, tuning system).
- One strategy for the verification of the RF system may be based on the verification of the modules and sub modules. Combination of these modules being managed by sorting.
- Thus, to be considered:
  - Power coupler conditioning.
  - One accelerating unit (2 cavities, 2 klystrons, 1 modulator).
  - One module (may include the previous case).
- Plus: simulations, analysis, reviews, manufacturing controls

In summary:
Model Based Systems Engineering

- The construction of the ESS will be paved by a huge number of:
  - products (most of them are not challenging),
  - processes (most of them are simple),
  - roles (all are important).
- And thus a huge number of interfaces.
- Most of the processes are common sense, but the quantity creates the complexity.
- This complexity can ONLY be managed by a systematic approach, documented.
- From this view, traceability from requirements to verification is mandatory.