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Architecture Design of Nuclear Power Plants Systems through Viewpoints-based Systems Analysis

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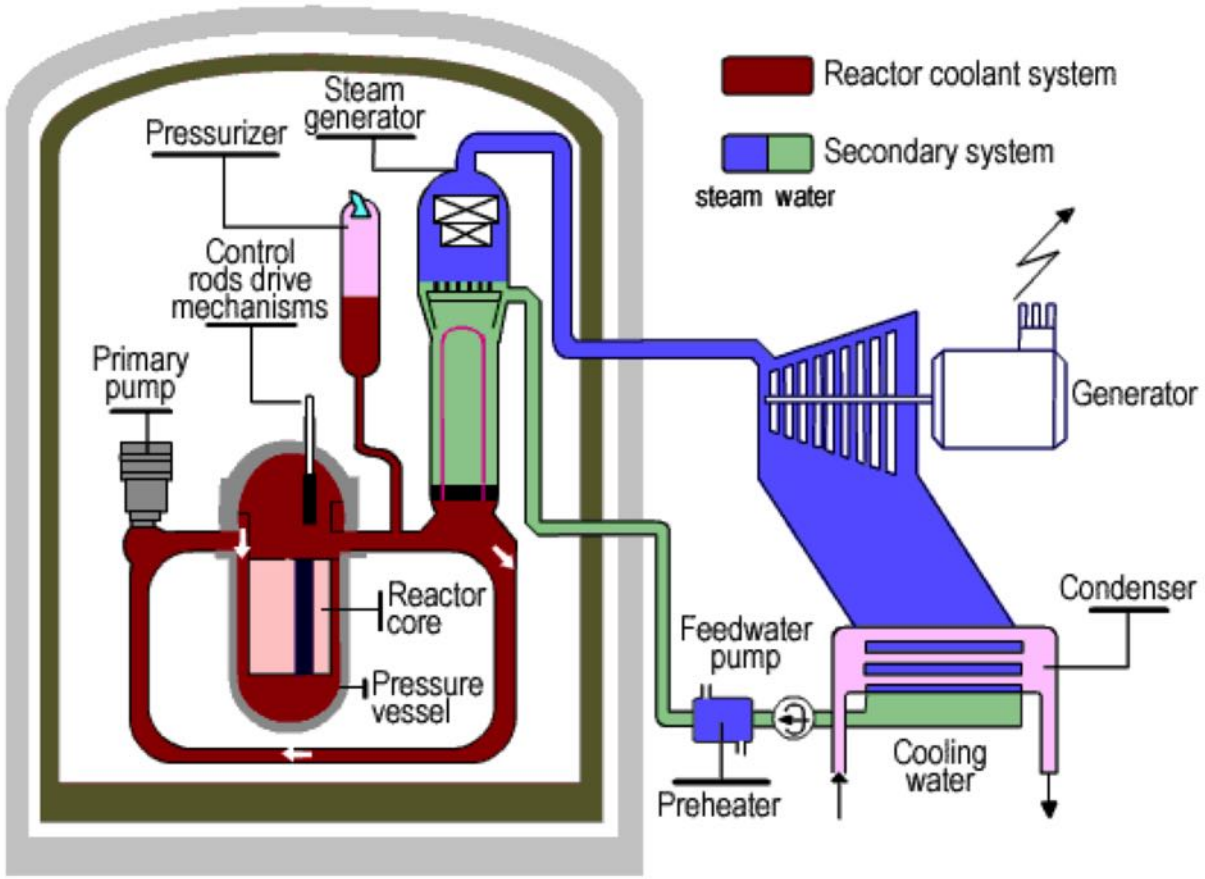
Clarity

Could a MBSE approach be effective on dealing with nuclear engineering challenges?

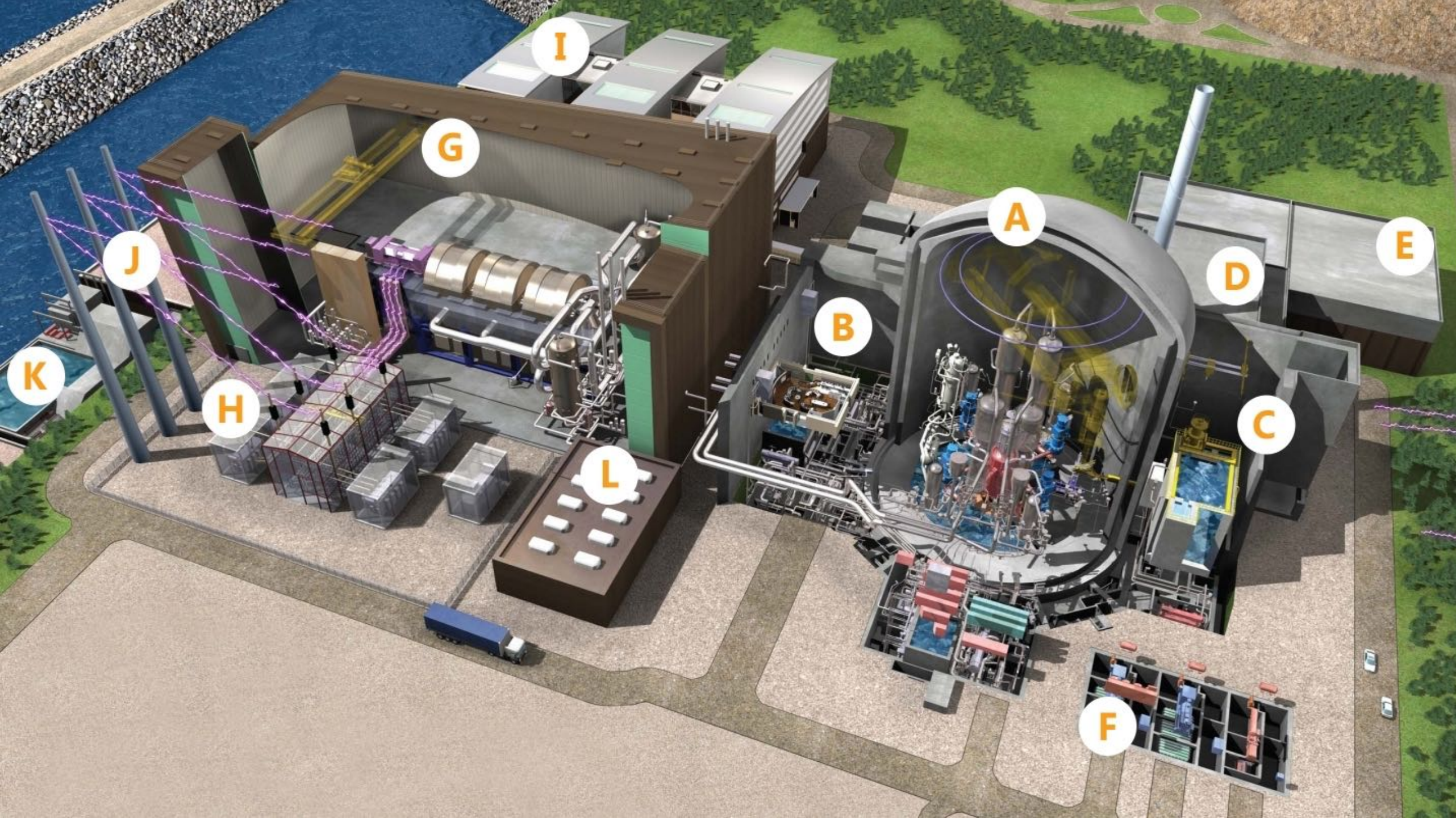
Stephane Bonnet

Jean-Luc Voirin

Nuclear Power Plants in a nutshell



- Pressurized Water Reactor (PWR)-type NPP principles are well known since the 1950's
- Business challenges of contemporary PWR NPP engineering include:
  - Development and integration of new technologies
  - New and harder safety requirements applicable the product and the engineering process
  - Tight construction schedules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SG weight = 2.5 x

1

Complexity

2

Arcadia

3

MBSE & NPP

4

Findings & Perspectives

1

Complexity

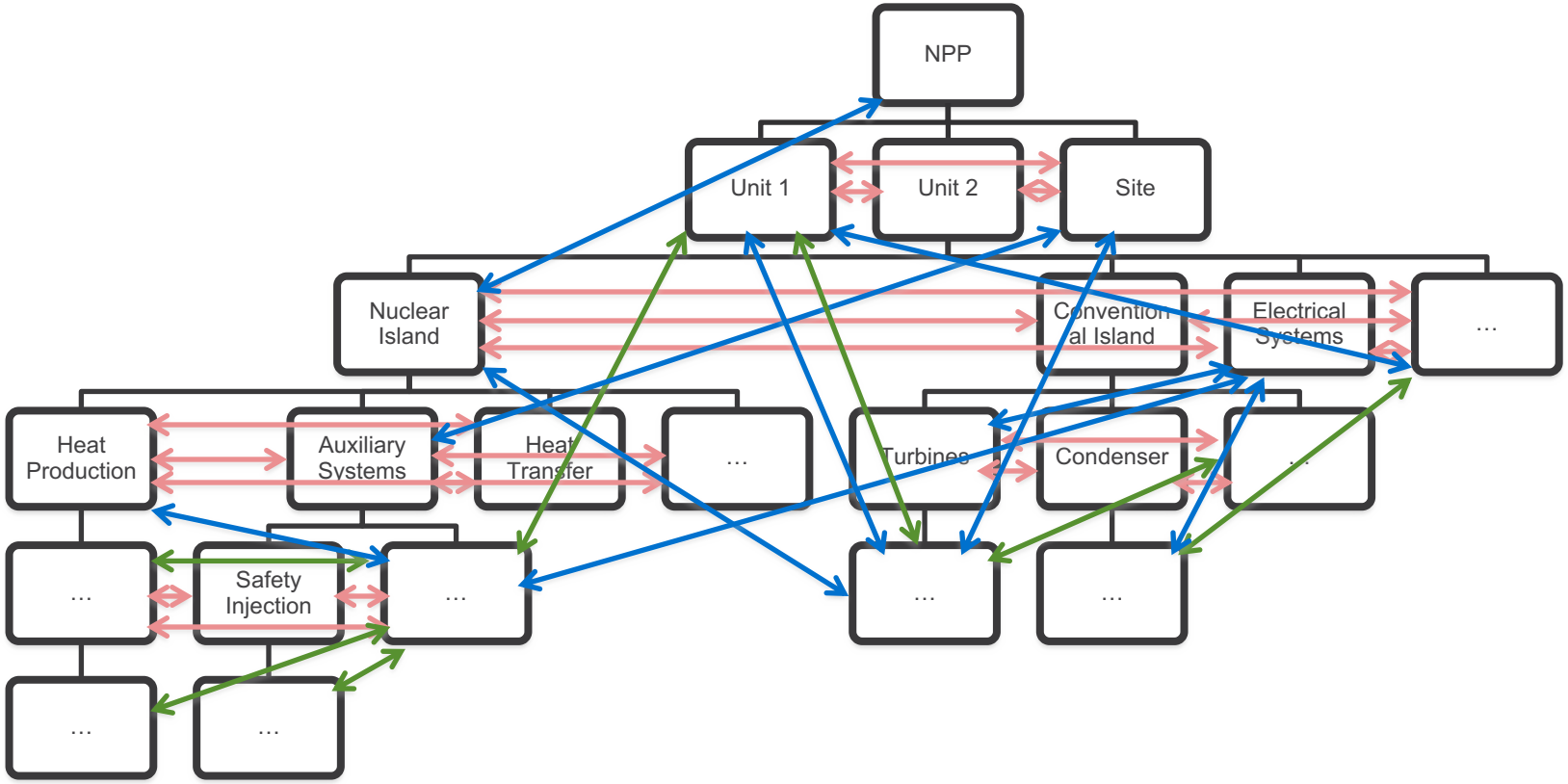
What are the challenges that nuclear engineering faces today

Complexity

"At first sight, complexity is a quantitative phenomenon, the extreme amount of interaction and interference between a very large number of units (…) [But] it also includes uncertainties, indeterminations, random phenomena".

Edgar Morin (1921 -), french philosopher and sociologist

Product complexity



Deep and rich PBS & Multiple viewpoints → Need to master interactions & interferences

Project complexity

External actors	Internal actors
• Very influential actors, not necessarily engaged and even resistant to the project • Strong influence of politics and public opinions	• High number of contributors and contributing organizations • Large amount of disciplines involved • Loss of knowledge by turnover

Large amount of stakeholders & Heterogeneous background → Need to use a common language

Product & Project complexity

Deep and rich PBS & Multiple viewpoints → Need to master interactions & interferences

Large amount of stakeholders & Heterogeneous background → Need to use a common language

2

Arcadia

Or how could Arcadia MBSE contribute to address these challenges

Arcadia MBSE scope

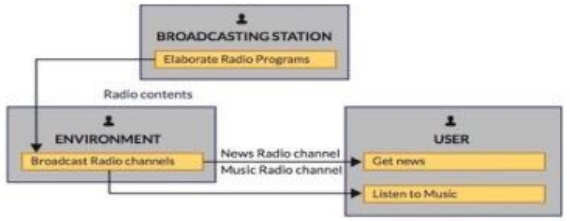
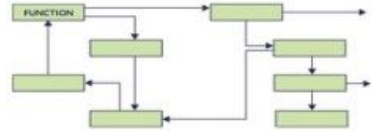
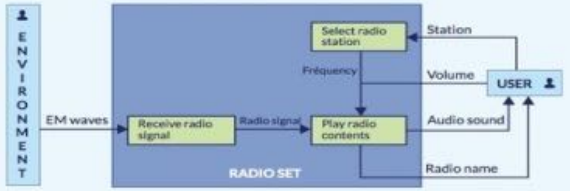
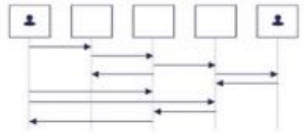
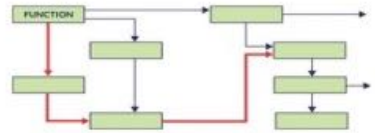
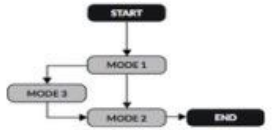
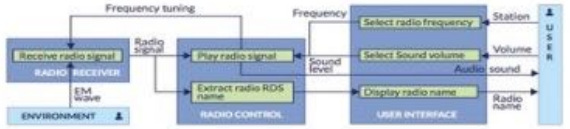
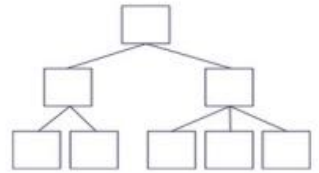
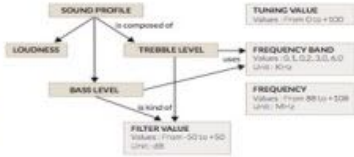
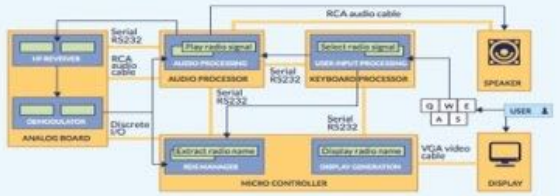
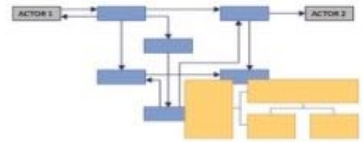
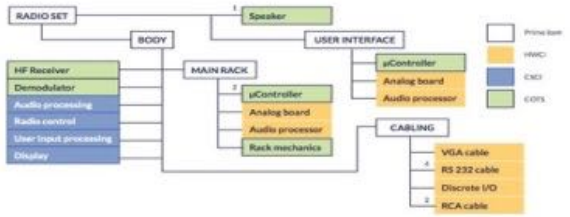
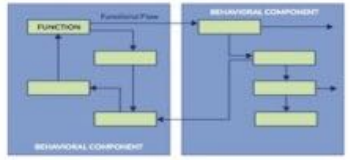
Understand the real customer need

Define and share the solution among stakeholders

Secure systems engineering, prepare subcontracting

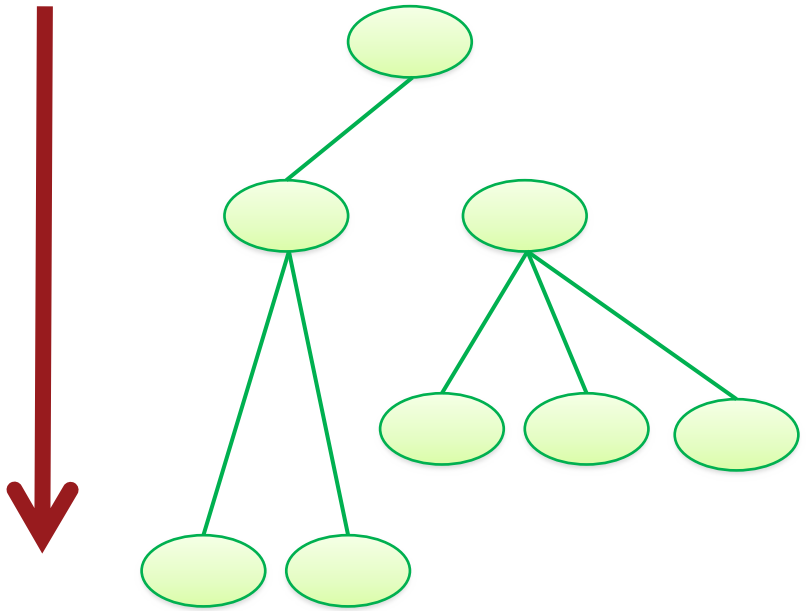
Early evaluate and justify architectural design

Prepare and master V&V

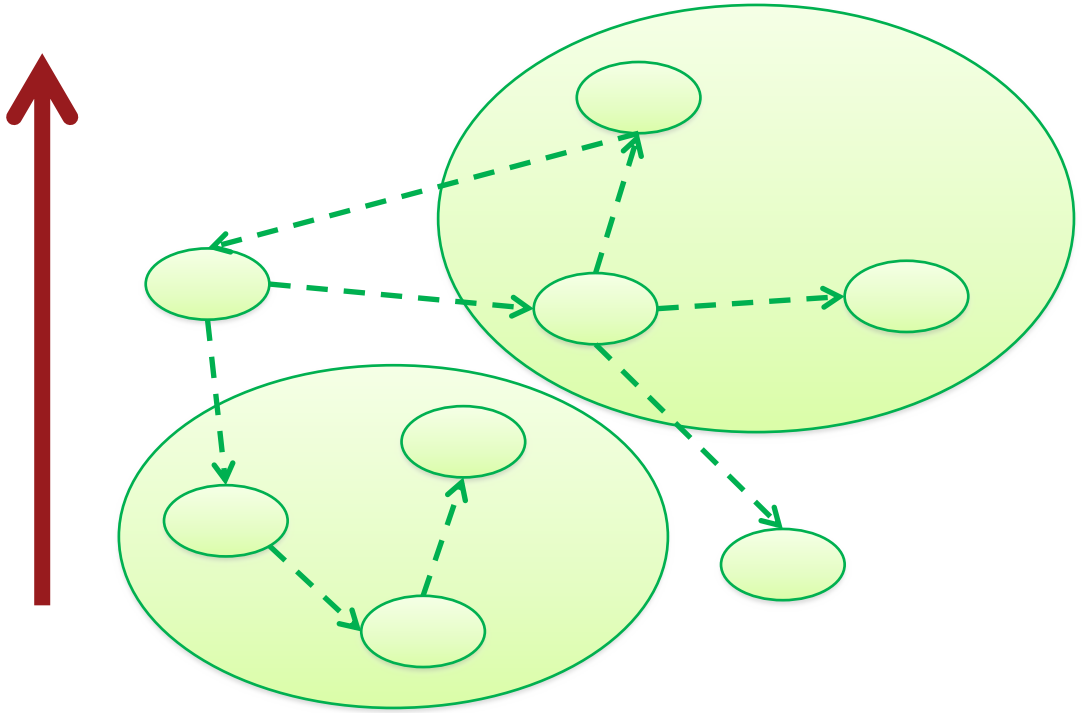
METHOD STEPS	TASKS	SAMPLE MODEL	CONCEPTS	DESCRIPTION MEANS
NEED				
Customer Operational Need Analysis What the users of the system need to accomplish	✓ Define operational capabilities ✓ Perform an operational need analysis		- Operational capabilities - Actors, operational entities - Actor activities - Interactions between activities & actors - Information used in activities & interactions - Operational processes chaining activities - Scenarios for dynamic behaviour	 **Dataflow:** functions, op. activities interactions & exchanges
System/ SW/HW Need Analysis What the system has to accomplish for the Users	✓ Perform a capability trade-off analysis ✓ Perform a functional and non-functional analysis ✓ Formalise and consolidate requirements		- Actors and system, capabilities - Functions of system & actors - Dataflow exchanges between functions - Functional chains traversing dataflow - Information used in functions & exchanges, data model - Scenarios for dynamic behaviour - Modes & states	**Scenarios:** actors, system, components interactions & exchanges   **Functional chains, operational processes** through functions & op. activities  **Modes & states** of actors, system, components
SOLUTIONS				
Logical Architecture Design How the system will work so as to fulfil expectations	✓ Define architecture drivers and viewpoints ✓ Build candidate architectural breakdowns in components ✓ Select best compromise architecture		*SAME CONCEPTS, PLUS :* - Components - Component ports and interfaces - Exchanges between components - Function allocation to components - Component interface justification by functional exchanges allocation	**Breakdown** of functions & components  **Data model:** dataflow & scenario contents, definition & justification of interfaces 
Physical Architecture Design How the system will be developed & built	✓ Define architectural patterns ✓ Consider reuse of existing assets design a physical ✓ Design a physical reference architecture ✓ Validate and check it		*SAME CONCEPTS, PLUS :* - Behavioural components refining logical ones, and implementing functional behaviour - Implementation components supplying resources for behavioural components - Physical links between implementation components	 **Component wiring:** all kinds of components
Development Contracts What is expected from each designer/ sub-contractor	✓ Define a components IVVQ strategy ✓ Define & enforce a PBS and component integration contract		- Configuration items tree - Parts numbers, quantities - Development contract (expected behaviour, interfaces, scenarios, resource consumption, non-functional properties…)	**Allocation** of op.activities to actors, of functions to components, of behav.components to impl.components, of dataflows to interfaces, of elements to configuration items 

Several workflows for functional analysis

Top down

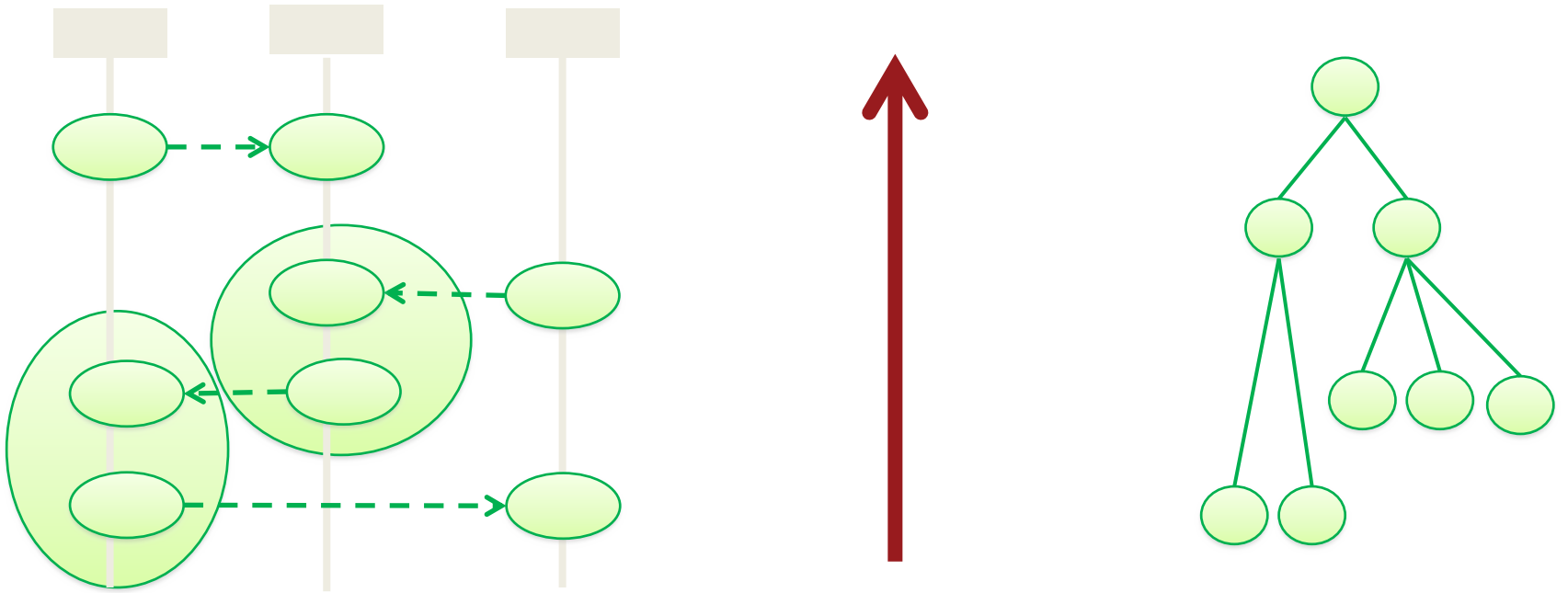


Bottom-up



Several workflows for functional analysis

Scenario-based bottom-up



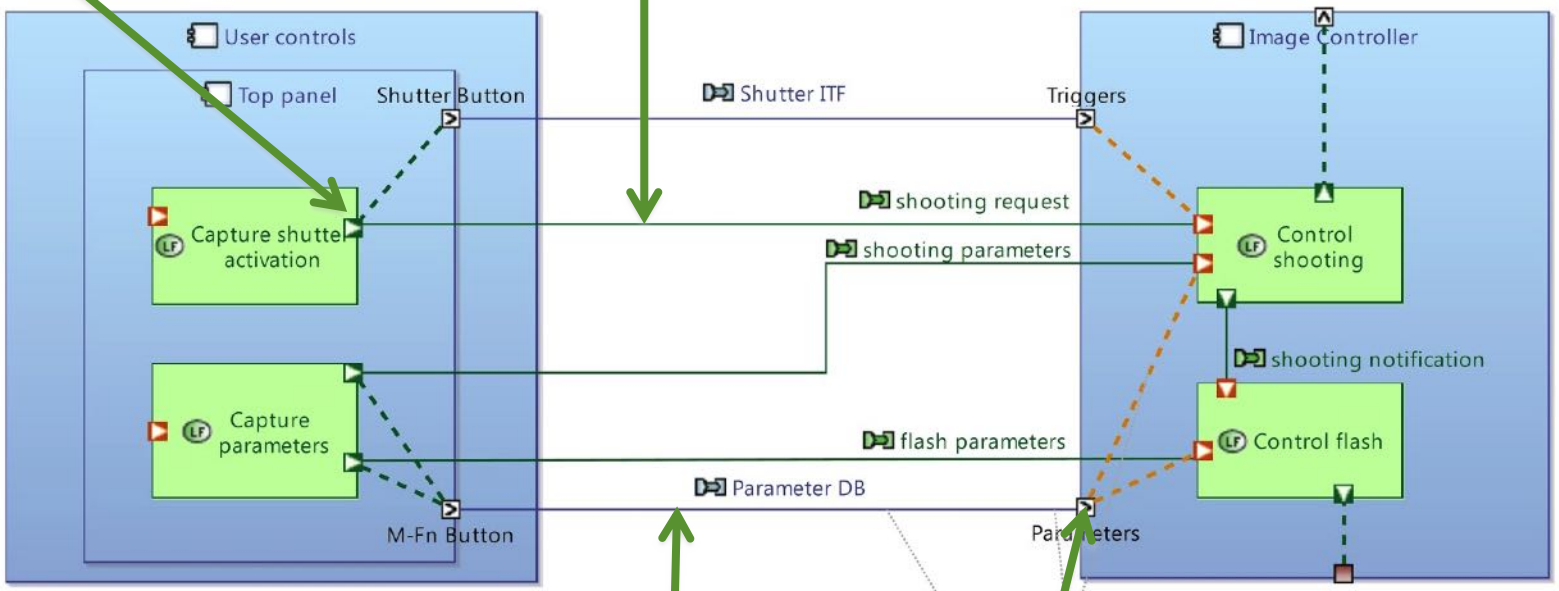
Focus on consistency of interfaces

Function ports specify expected/provided exchange items

Functional exchanges carry Exchange Items

Exchange Items are sets of data/physical flows exchanged simultaneously

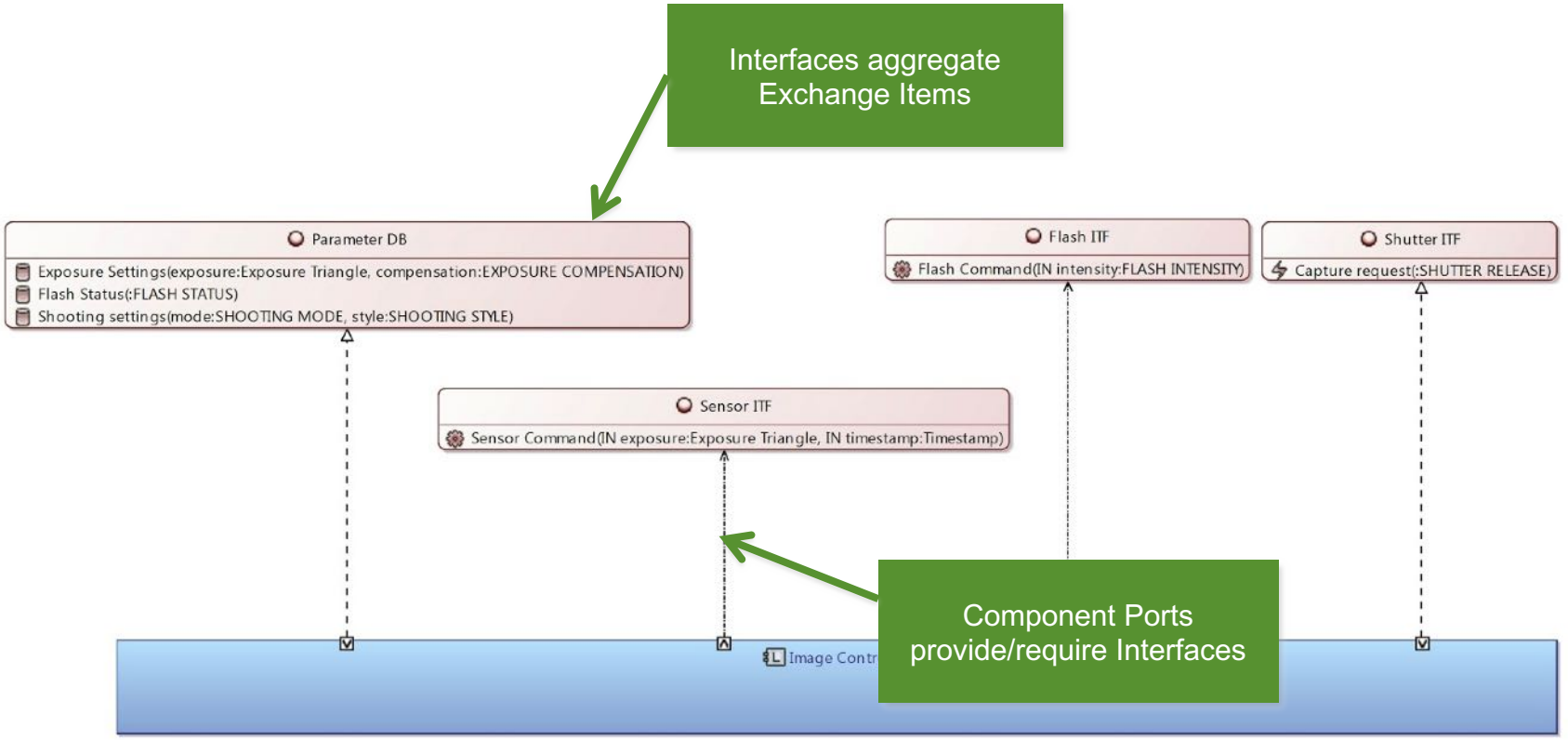
Data/physical flows descriptions



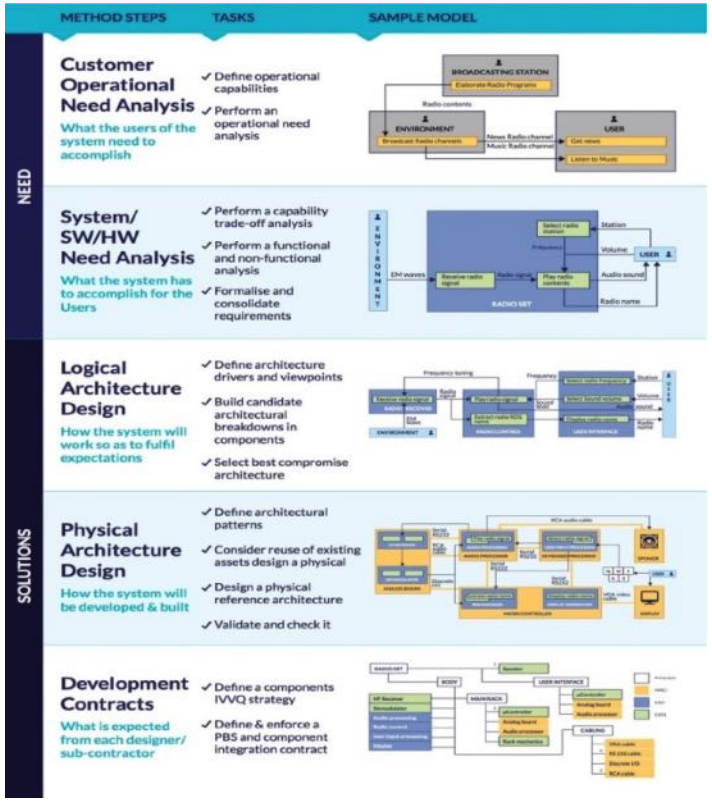
Functional Exchanges are allocated to Component Exchanges

Function ports are allocated to component ports

Focus on consistency of interfaces



Tight coupling of method & tool



ARCADIA

Capella

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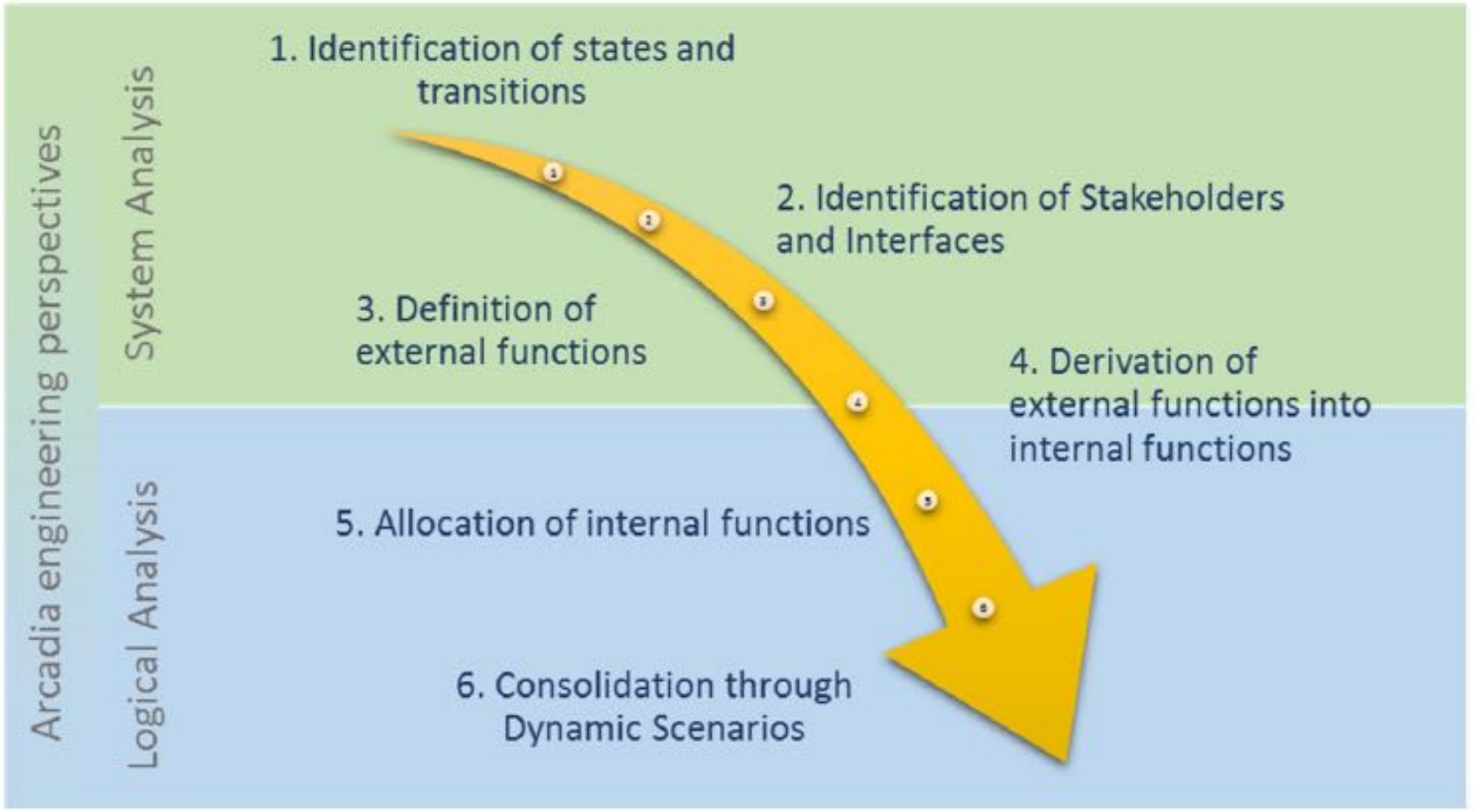
MBSE & NPP

Or how Arcadia MBSE was tailored to address complexity in NPP engineering – Nuclear Island case study

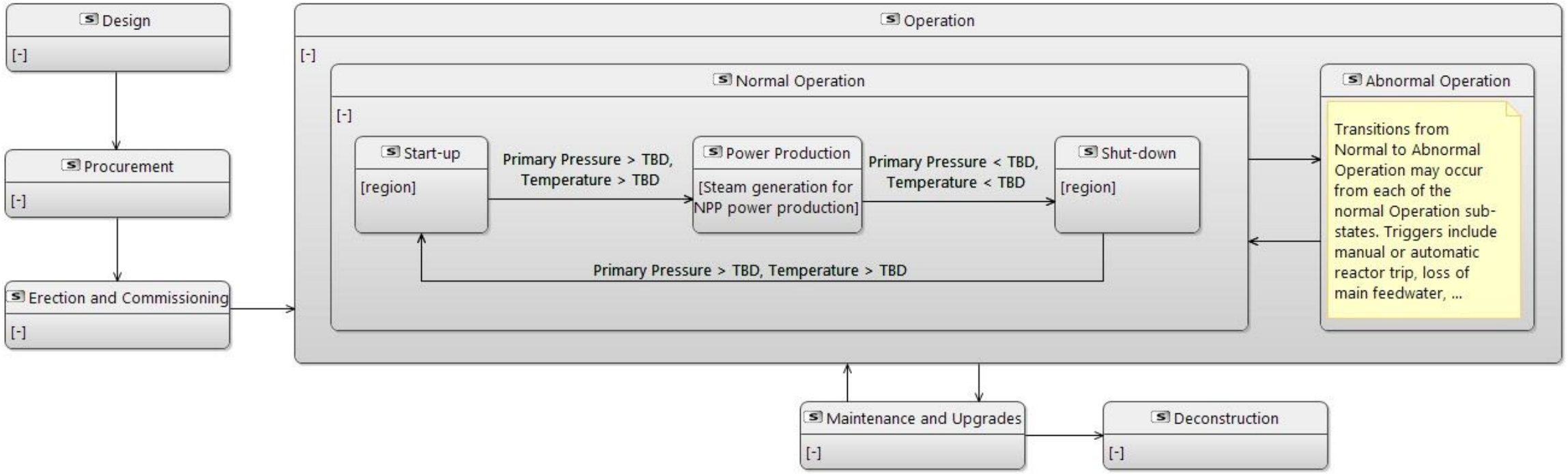
Overview


Arcadia engineering perspectives
System Analysis
Logical Analysis
1. Identification of states and transitions
2. Identification of Stakeholders and Interfaces
3. Definition of external functions
4. Derivation of external functions into internal functions
5. Allocation of internal functions
6. Consolidation through Dynamic Scenarios

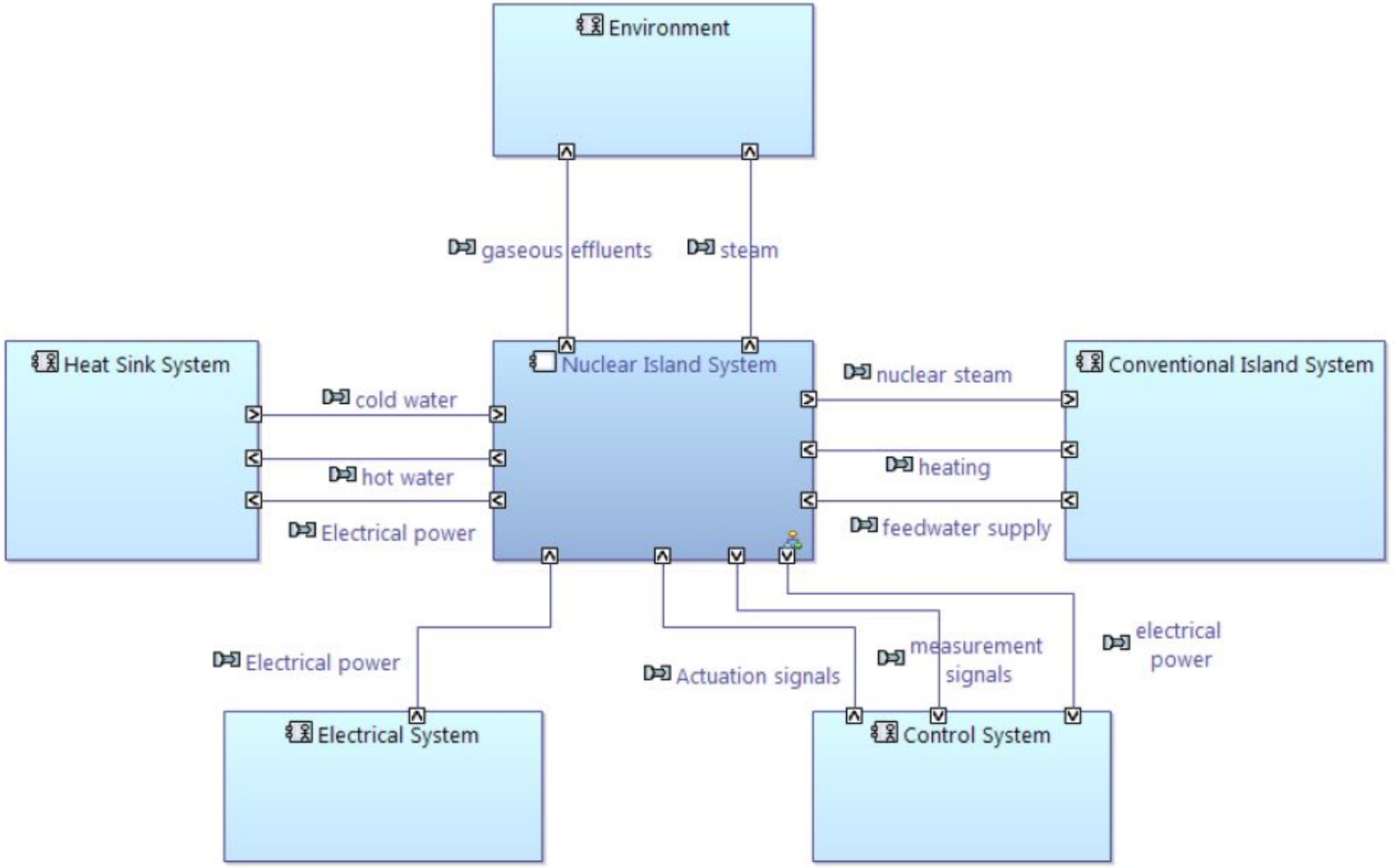
Overview (1)

	Task	Main outcome of the views	Process
1	Identification of states and transitions	Preliminary framework of life-cycle stages of the SOI to be considered in the design phase.	It may evolve during method execution.
2	Identification of stakeholders and interfaces	Stakeholders interacting or interfering with the SOI during its life-cycle stages.	Views are progressively refined and enriched with functional and non-functional requirements during method execution.
3	Definition of external functions	SOI functions derived from interactions with stakeholders.	Performed in a collaborative way, ensuring the consistency with the external functions of the systems the SOI interacts with.
4	Derivation of external functions	Less complex internal functions	Issued from the decomposition of external functions following the life-cycle stages. Includes requirements' derivation as well.
5	Allocation of internal functions	Allocation of internal functions and requirements into the PBS reference architecture.	The allocation and the function decomposition is evaluated (trade-offs) with regards to SOI business goals.
6	Consolidation of the architecture	Consolidated architecture.	Architecture is challenged with scenarios to check that the functions and requirements properly specify the expected behavior of the SOI.

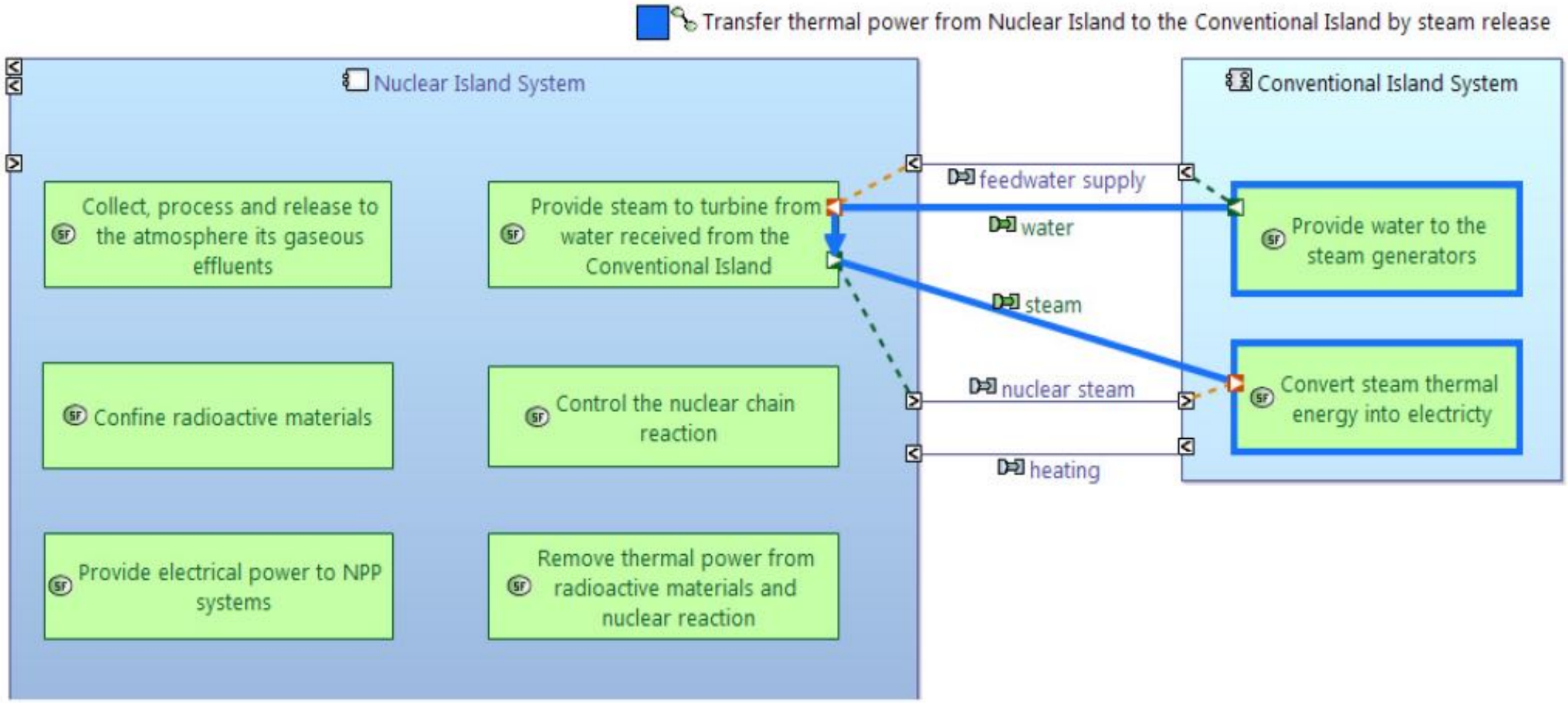
Identification of states and transitions



Identification of stakeholders and interfaces



Definition of external functions



Overview (2)

	Task	Main outcome of the views	Process
1	Identification of states and transitions	Preliminary framework of life-cycle stages of the SOI to be considered in the design phase.	It may evolve during method execution.
2	Identification of stakeholders and interfaces	Stakeholders interacting or interfering with the SOI during its life-cycle stages.	Views are progressively refined and enriched with functional and non-functional requirements during method execution.
3	Definition of external functions	SOI functions derived from interactions with stakeholders.	Performed in a collaborative way, ensuring the consistency with the external functions of the systems the SOI interacts with.
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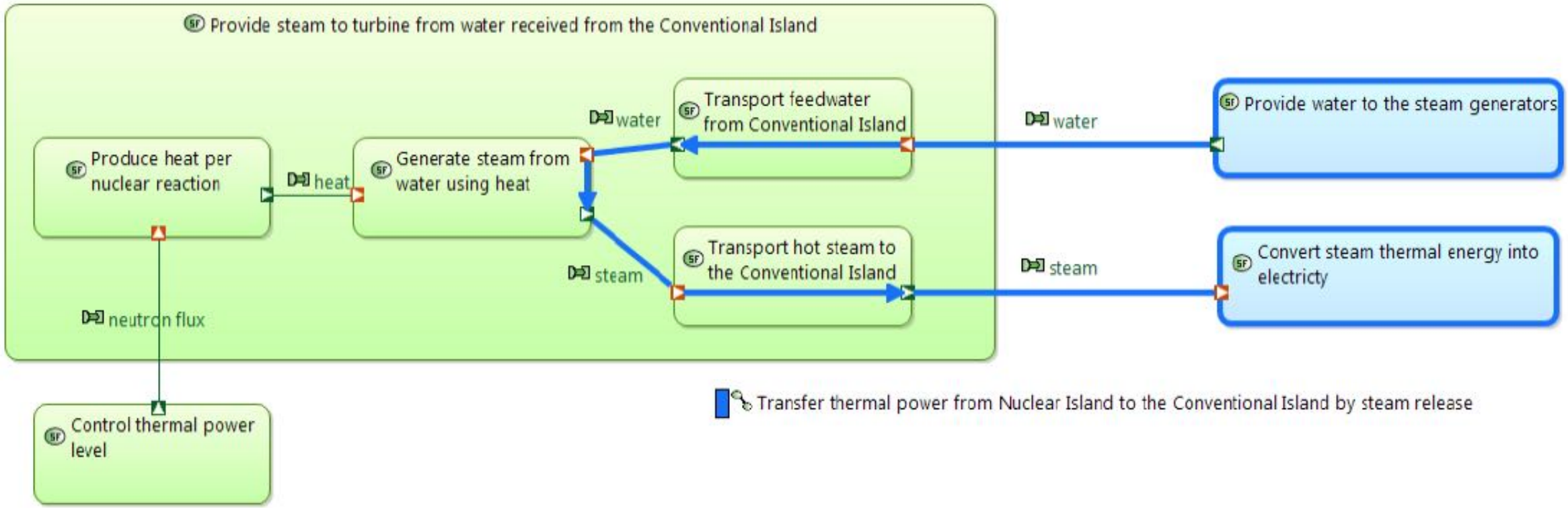
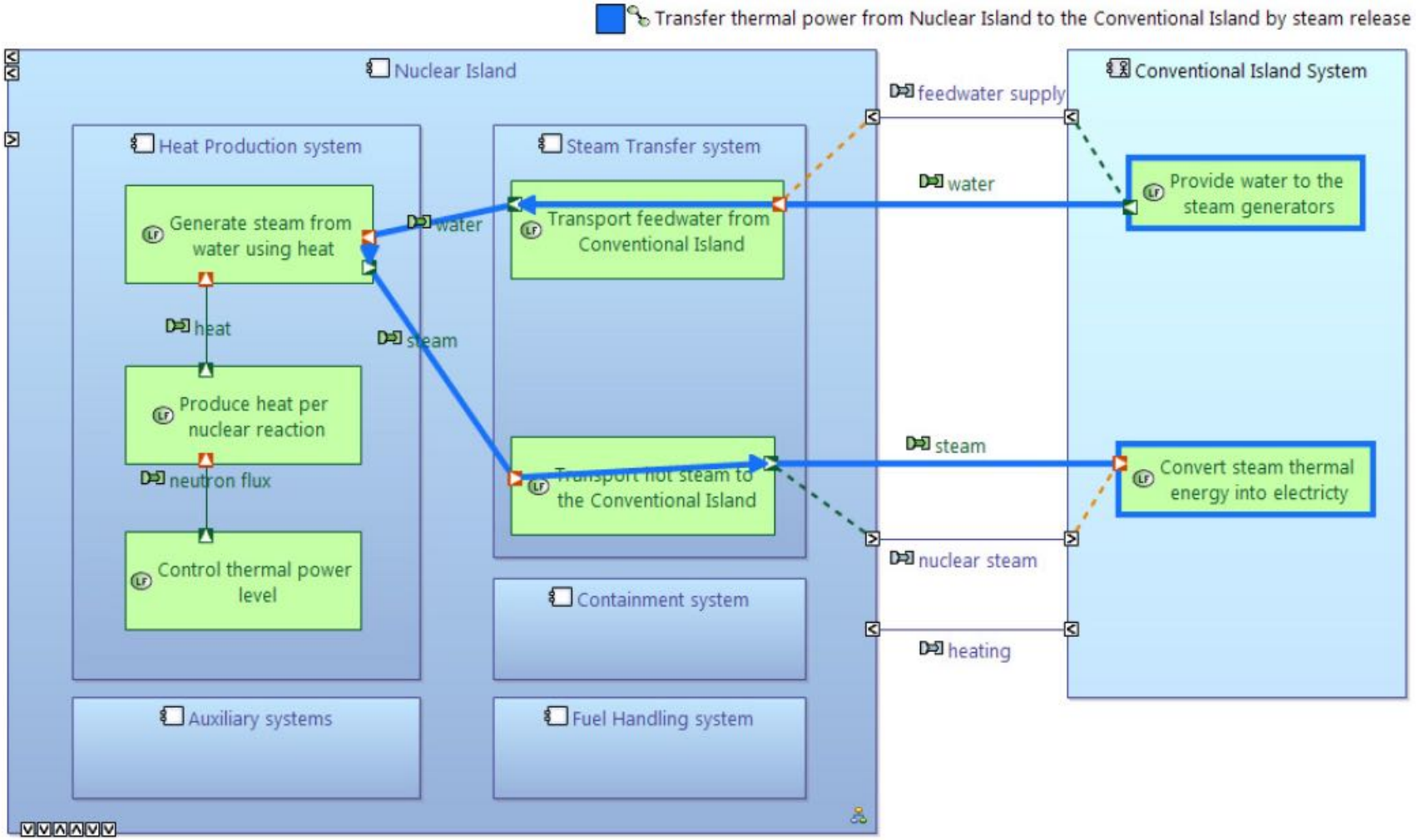
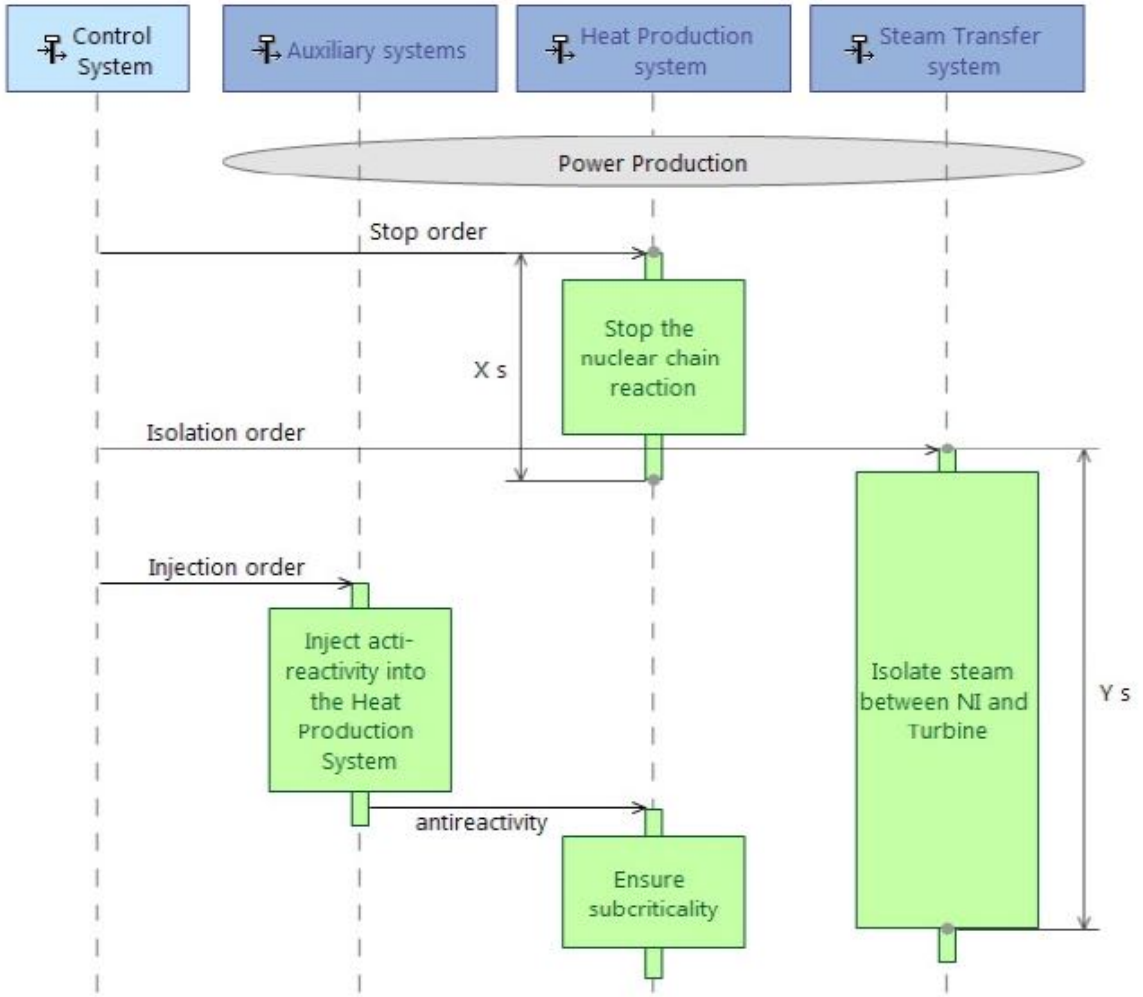
Derivation of external functions



Allocation of internal functions



Consolidation of the architecture



4

Findings & Perspectives

Or how Arcadia MBSE was tailored to address complexity in NPP engineering

MBSE contributions to manage complexity

Enhanced communication	• Reduced set of shared concepts • Functional Chains as basis for cross-cutting analysis • An unique source of information
Improved Interfaces management	• Collaborative, productive and comprehensive definition of technical interfaces • Clearer definition of responsibilities and boundaries
Method tailoring	• Feasibility of tailoring at different PBS levels and SOI nature • Fast learning curve • Tooled multi-disciplinary trade-offs

Perspectives

Trade-offs

- Design and develop trade-offs capabilities following major architectural concerns (e.g. safety, HFE, IVVQ, …)

Leverage models

- Leverage architectural models
  - In other technical processes
  - In technical management processes

More information on Arcadia & Capella

- Capella Booth #15
  - Demonstrations, general information, contacts

- Capella Webinars at YouTube « Capella Polarsys » channel, e.g.
  - « Equivalences and differences between Arcadia/Capella and SysML »
  - « How is Capella different »

- « Commented Arcadia/Capella model » Webinars
  - Describing a system model that covers all layers of Arcadia

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www.incose.org/symp2018

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