A Model-Based Engineering Method for System, Software and Hardware Architectural Design

ARCADIA

A method best-supported by

Capella

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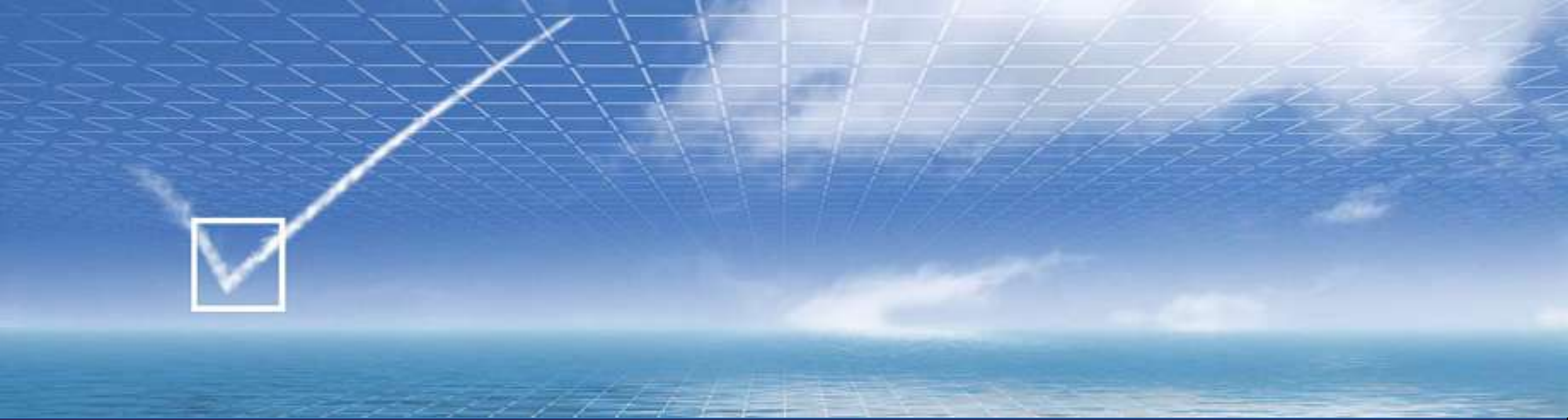
Foreword

This set of slides is a light introduction to Arcadia. The method is today extensively detailed through different Thales documents which are not publicly available: Reference guide, practitioner's guide, encyclopedia of concepts, etc. Fully publishing publicly the detailed Arcadia method is a major objective of the 3-years Clarity consortium. This will however not be immediate, as a significant work is necessary to remove Thales references and find the best support (books, standardization technical reports, etc.).

The public publishing process will also probably lead to an adaptation of some of the Arcadia existing terminology. Without changing the goals and semantics of the Arcadia current content, a few concepts will most likely be renamed.

For any question about the method and its usage within Thales or to directly exchange with us, please contact arcadia-contact@thalesgroup.com

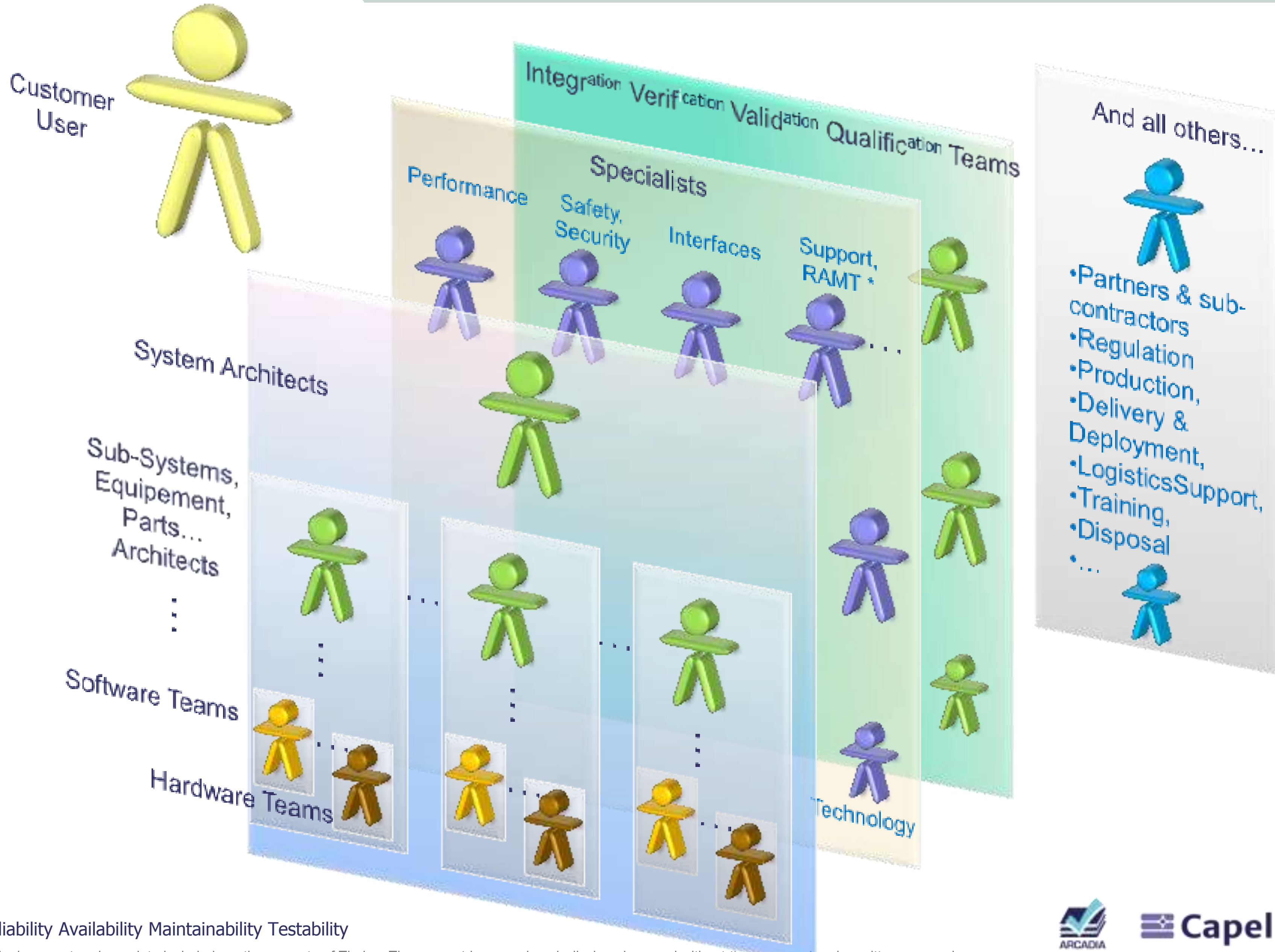
Contents



Current Engineering Practices and Gaps

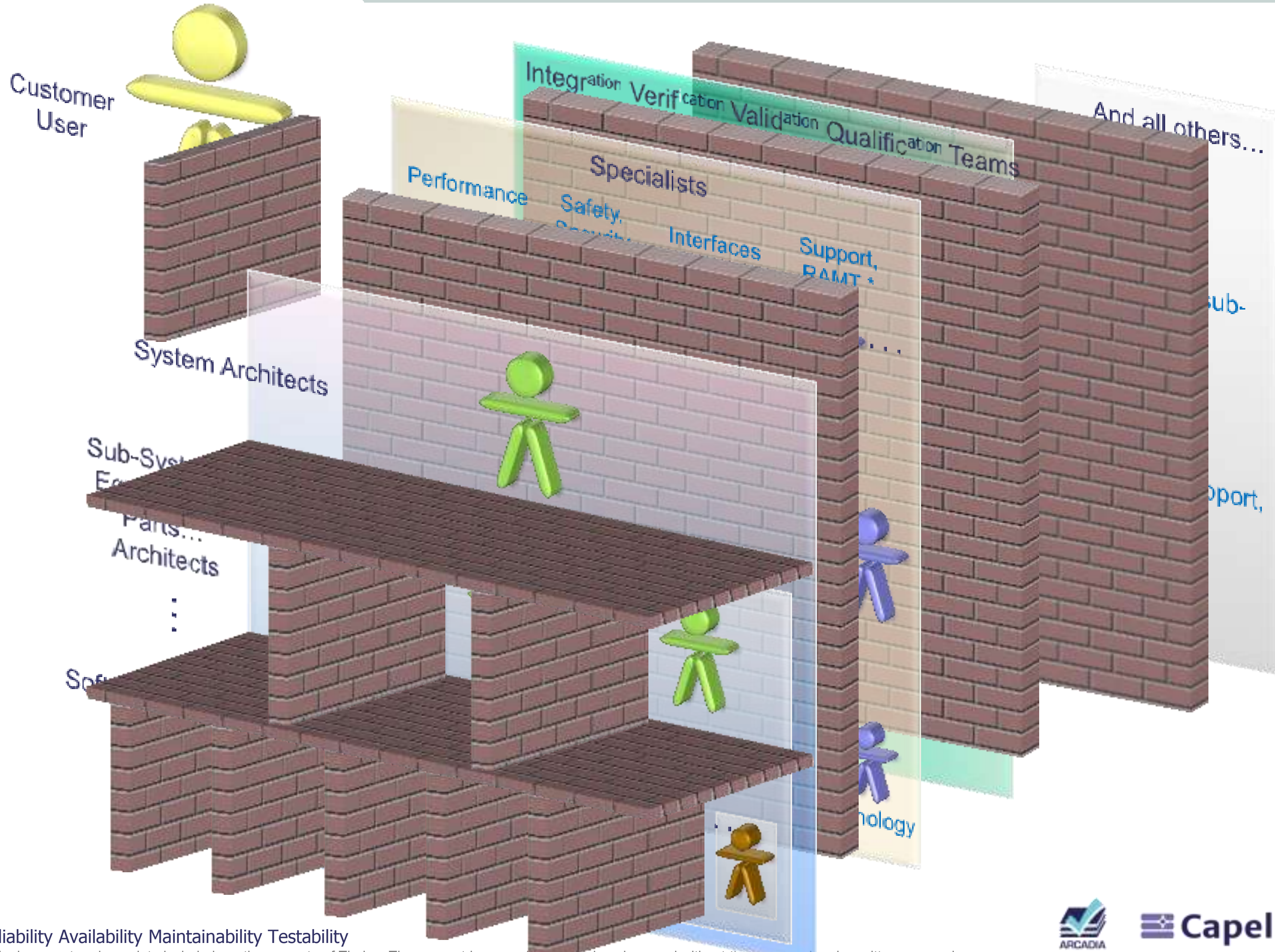
Engineering practices and their limits

The System Engineering « Ecosystem » Challenge: Collaboration



* RAMT: Reliability Availability Maintainability Testability

The System Engineering « Ecosystem » Challenge: Collaboration



* RAMT: Reliability Availability Maintainability Testability

Seven Deadly Sins* in System Engineering

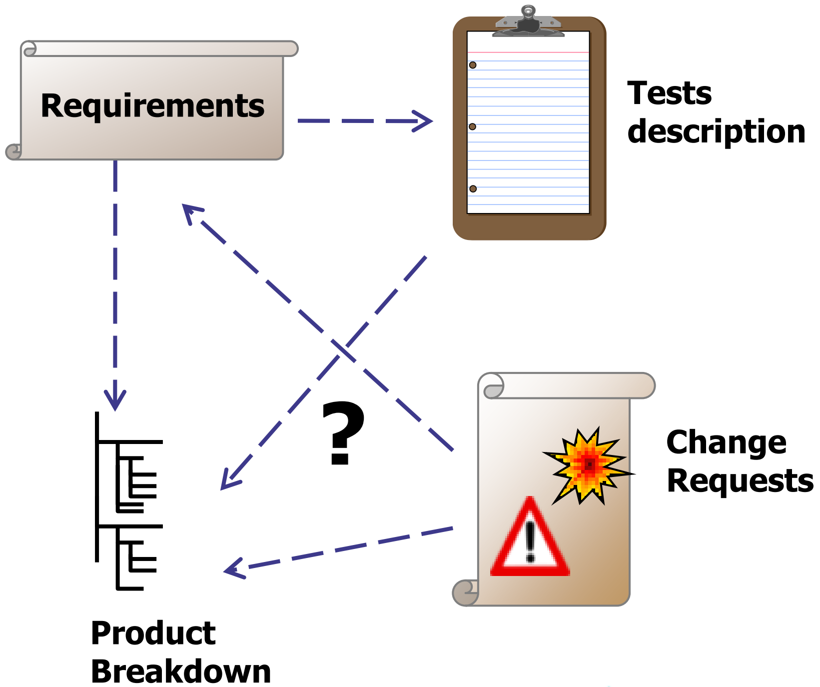
- "Full Requirements driven approach weaknesses"
- Bad understanding of CONOPS/CONUSE**
- Incoherent reference & decisions between engineering specialties
- Poor continuity between engineering levels
- Late discovery of problems in definition & architecture
- Underestimated Architectural Design impact / benefit
- No anticipation of IV&V, no functional mastering
- No justification, no capitalisation for reuse/product line

* Deadly Sins: Péchés capitaux
** CONcepts of OPerationS, CONcepts of USE
*** IV&V : integration, verification, validation

Limits of Textual Requirements-Driven Engineering

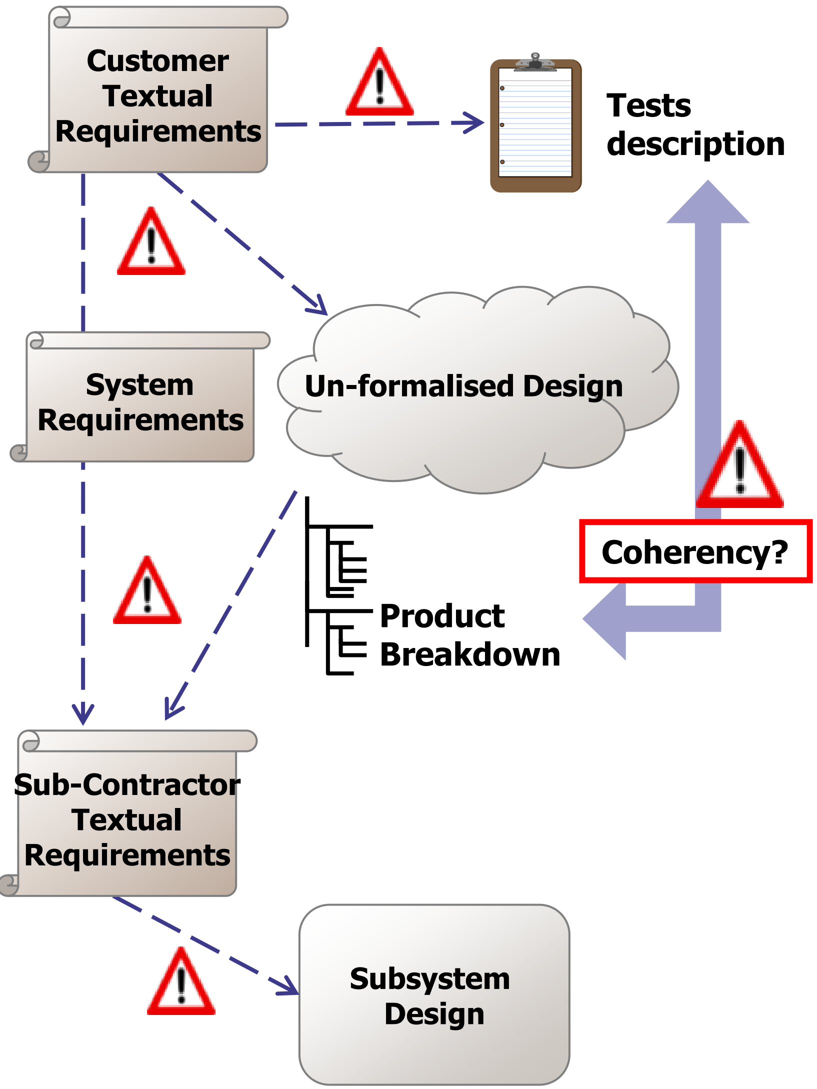
- Textual requirements are today the main vector of technical management contract with the customer

- However they have significant limitations:
  - Informally described and not adapted to validation by formal methods
  - Inadequate to support Design
  - Unable to describe a solution
  - Traceability links Creation process unclear and hard to formalize
  - Traceability links unverifiable
  - Difficulties to securely reuse requirements alone
  - …

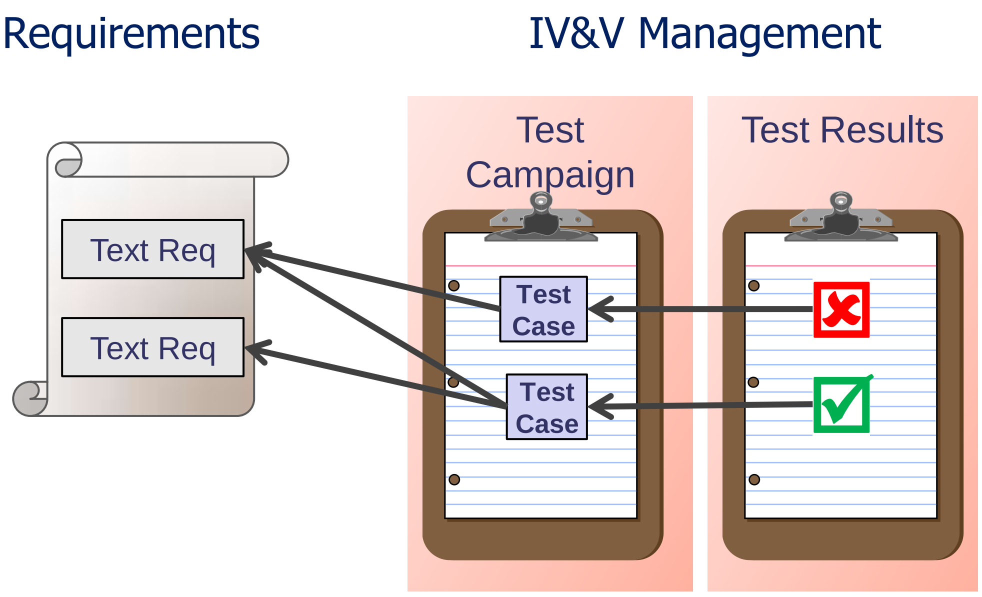


Requirement-Based Approach

Definition and subsystem specification



Requirement validation process



IV&V : integration, verification, validation

Some Consequences on Engineering

- No solution is described, only requirements allocation
- Definition of suppliers delivery is weak and not sufficient
- Checking quality of the definition is not possible before IV&V
- Thus, justification of definition is poor and unreliable
  - Components functional contents, behaviour, interface definition…
- Examples of consequences in IV&V :
  - Poor control of versioning and complexity
  - Missing components when verifying a requirement
  - No mastering of the consequences of non-maturities (PCR ...)
  - Poor mastering of behaviour(startup, non nominal states ...)
  - Difficulty in organizing / optimizing regression tests
  - Difficulty of locating faults and impact analysis ...

- These problems increase along with system or project complexity

IVV : integration, verification, validation

ARCADIA Goals and Action Means

Solving the walls issue

A tooled method devoted to systems, software and hardware Architecture Engineering

- To understand the real **customer need**,
- To define and **share** the system **architecture** among stakeholders,
- To **early validate** system design and **justify** it,
- To ease and **master IVVQ** (Integration, Validation, Verification, Qualification).

→ Improve efficiency and quality of System Engineering
→ Master complexity of products
→ Foster and secure collaborative work of engineering stakeholders
→ Reduce development Costs & Schedule

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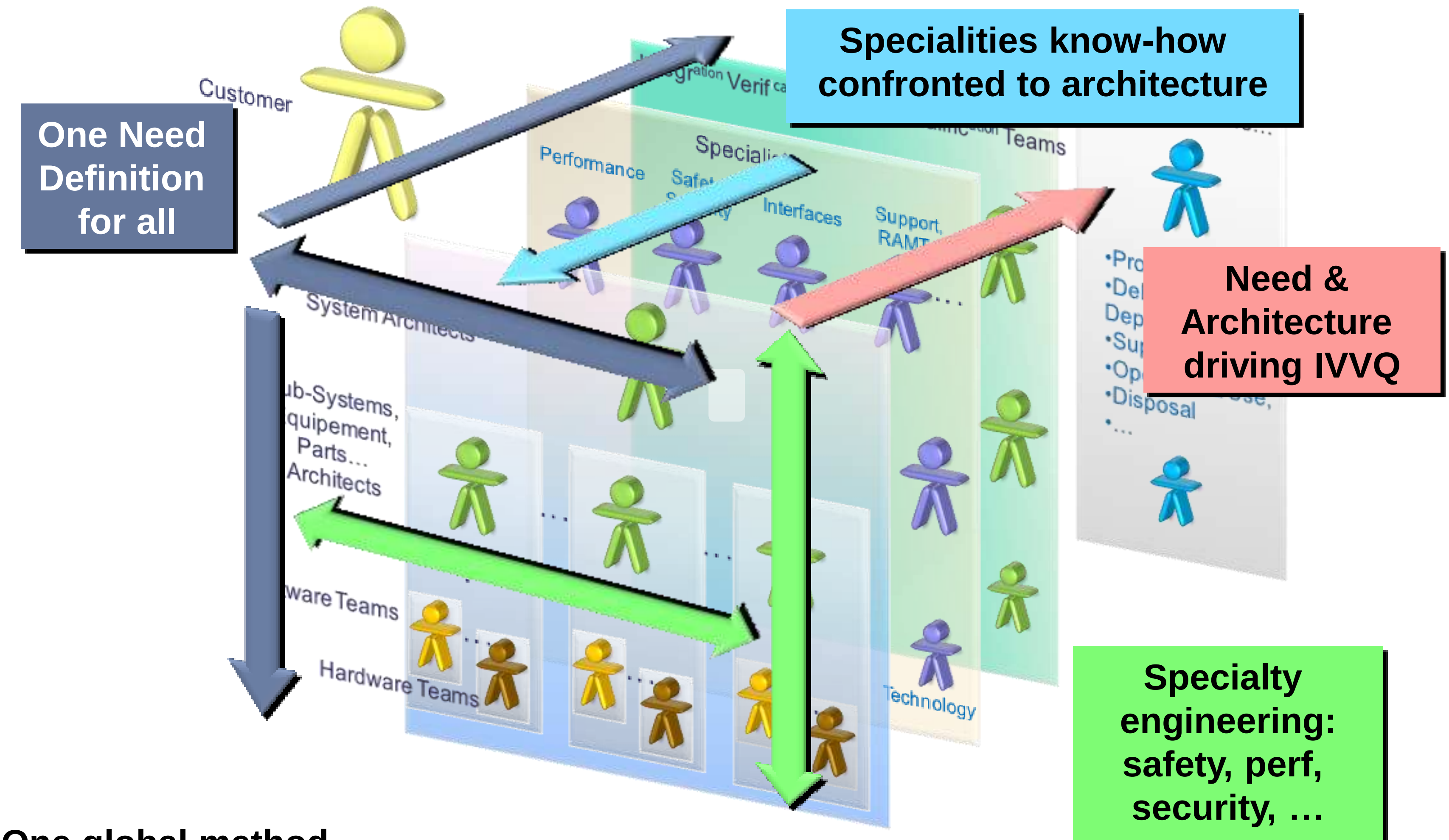
ARCADIA Action Means – Engineering Collaboration



One global method, adaptable/adapted to each domain

Seven Cardinal Virtues in System Engineering

~~☹ *Bad understanding of operational use*~~

~~☹ *Incoherent reference & decisions between engineering specialties*~~

~~☹ *Poor continuity between engineering levels*~~

~~☹ *Late discovery of definition & architecture problems*~~

~~☹ *Underestimated Architecture impact / benefit*~~

~~☹ *No anticipation of IVVQ, no functional mastering*~~

~~☹ *No justification, no capitalisation for reuse/product line*~~

Analyse and formalise **stakeholders need**:
operational scenarios & processes, functional & non-functional need

Drive specialties through **a unique, shared reference**;
coordinate and evaluate global impact of decisions on it

Share **reference** between **engineering levels**;
secure its application for impact analysis

Early check **the technical solution**
against Oper/Funct/NF need as well as against engineering constraints

Use **architecture to strengthen engineering**
according to engineering stakes

Manage **IV&V** using the **common functional reference** to schedule, define and master it

Capitalise by formalising **definition and design**, including decisions & justifications

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JLV

What Arcadia Is and Is Not

ARCADIA is NOT…

- ☹ *An academic work or a tool-vendor offer; Tested on toy problems*
- ☹ *Designed for traditional, top-down, waterfall or « V » lifecycle*
- ☹ *Only for large / complex projects*
- ☹ *Only for projects starting from scratch*
- ☹ *Only for software-dominant, or large system engineering, or…*
- ☹ *Costly and complex to set and use*
- ☹ *Restricted to system definition phase*
- ☹ *Too un-mature to be used yet*

ARCADIA is…

A set of practices **specified and tested by real projects engineers** wanting to address their top priority needs

Designed for adaptation to most processes and lifecycle constraints : bottom-up, legacy reuse, incremental, iterative, partial…

Used for bids and partial problems, down-scalable

Dealing with reuse, reverse engineering, evolution mastering, hot spots addressing

Used for thermal and power as well as information systems or software… architectures

Adjustable: **Focus on your major problems first and you will get ROI**

Also addressing & easing IV&V (integration verification validation)
Tested in tens of operational contexts

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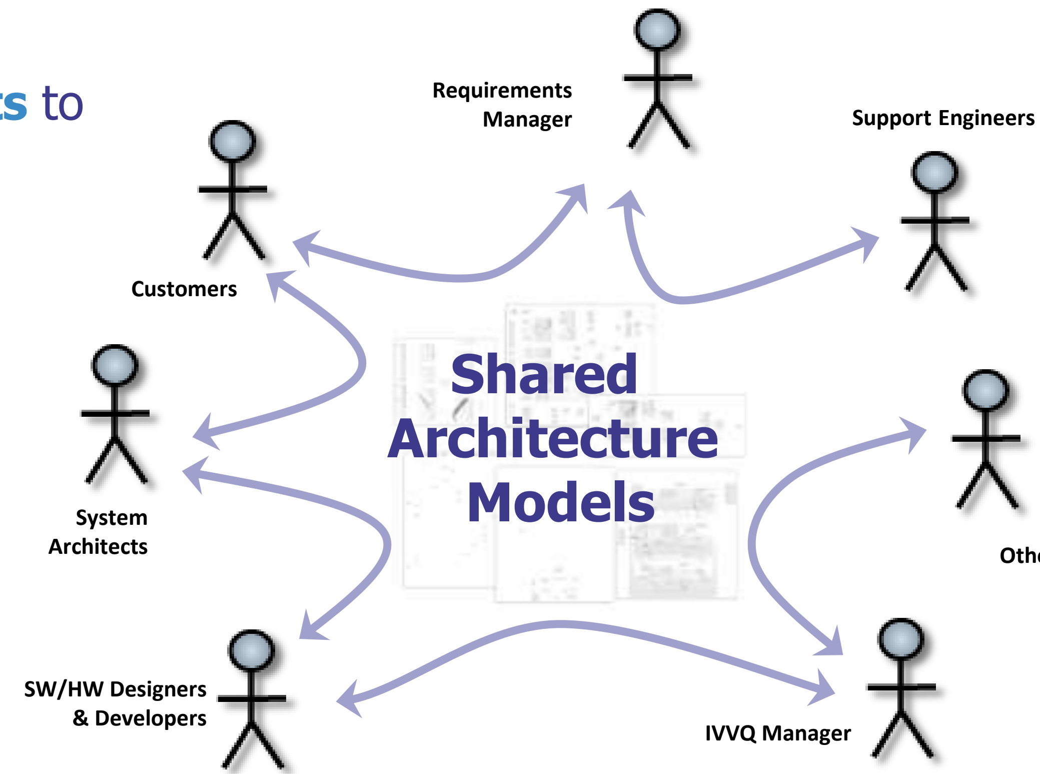
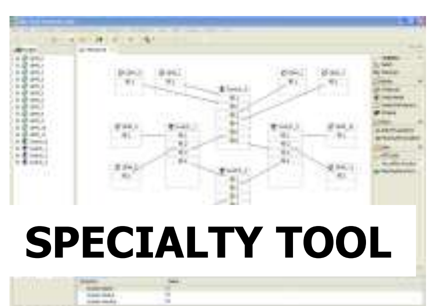
Needs to Support Collaborative Architecture Building

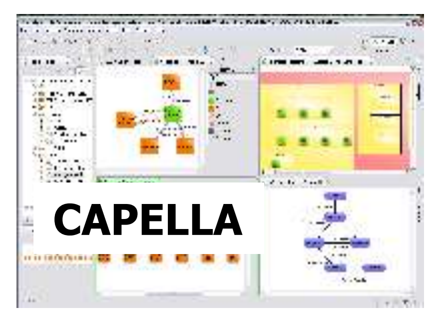
1. Common unified concepts to structure engineering :
Product-centric description & capitalisation

2. Collaborative workflow
Based on **shared description and unique reference**

3. Architecture Analysis Capability & Tools







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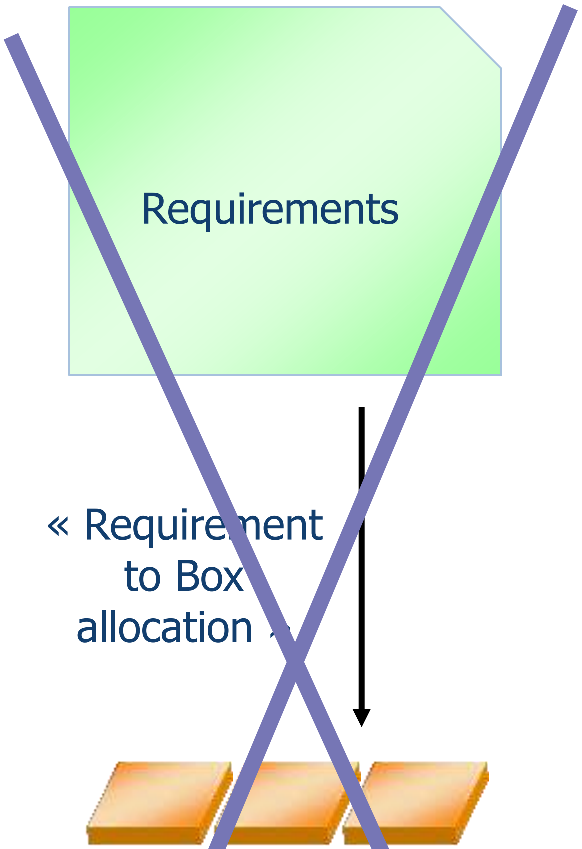
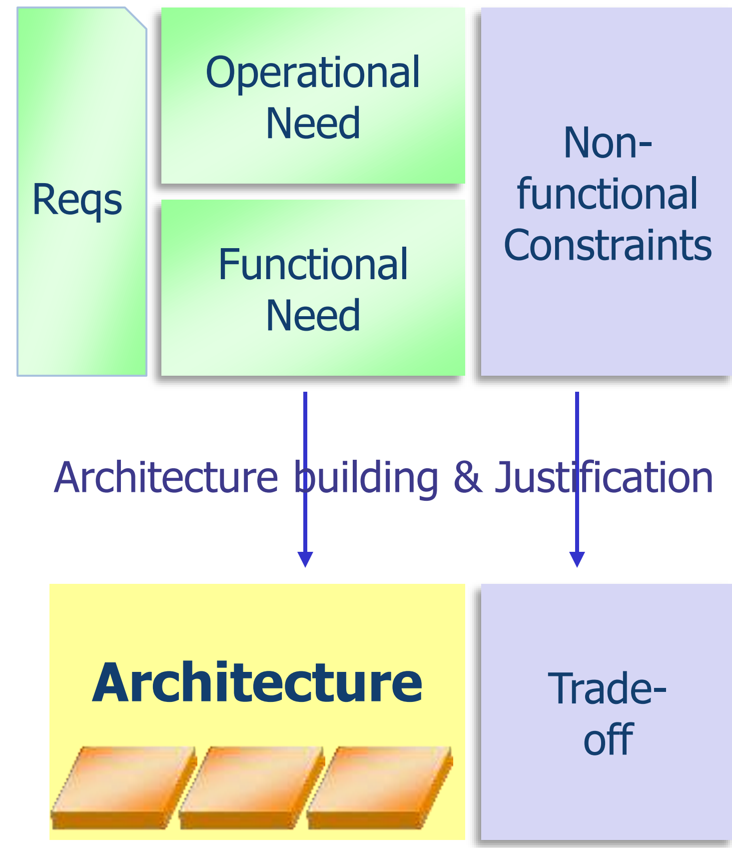
From Requirements Allocation to Architecture Mastering





Late discovery of design issues during IVV
(Integration, Verification, Validation)

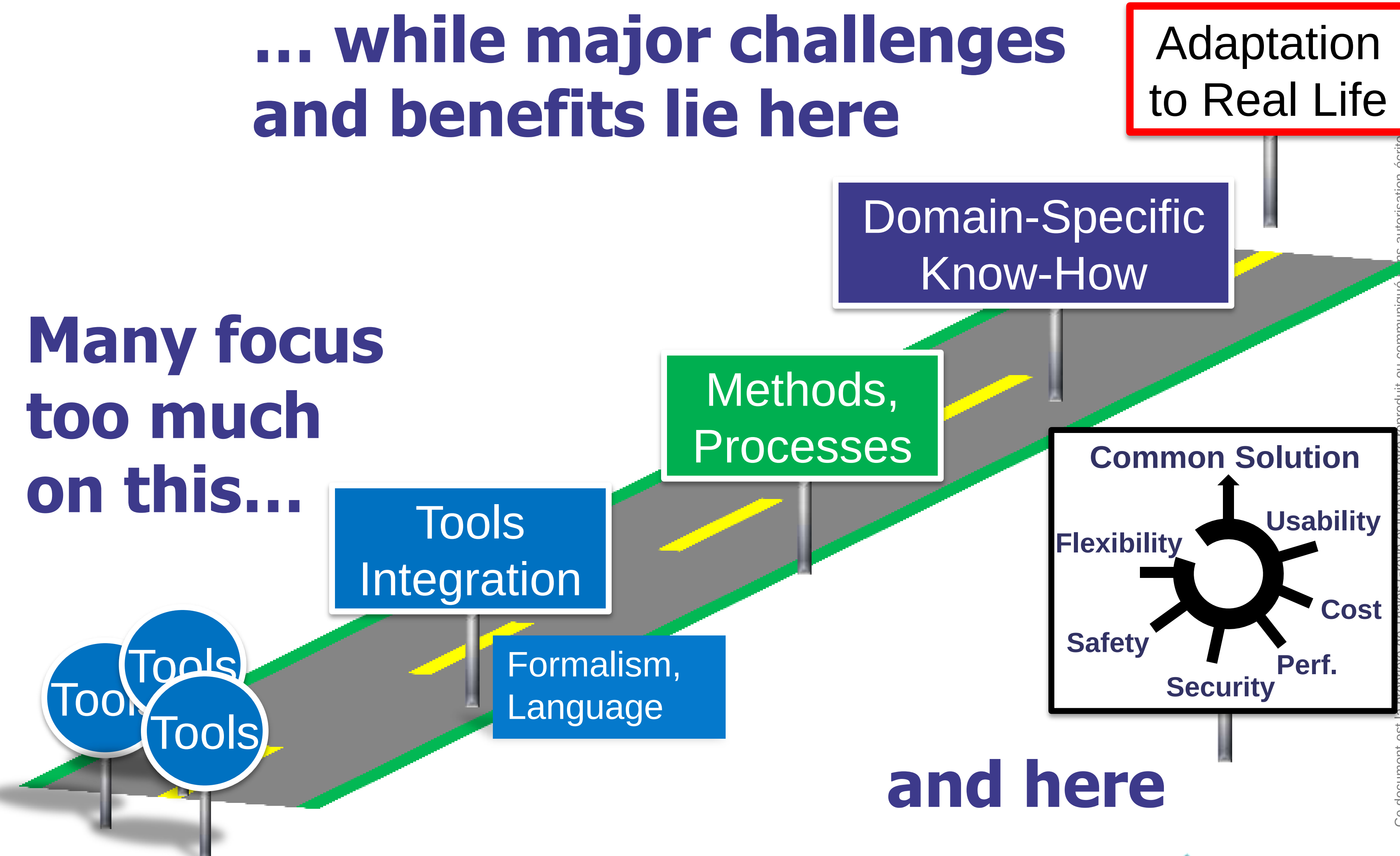
Early validation of the architecture

Mastering and optimisation of product and IV&V

The Long Way to Master Complexity…

… while major challenges and benefits lie here

Many focus too much on this…



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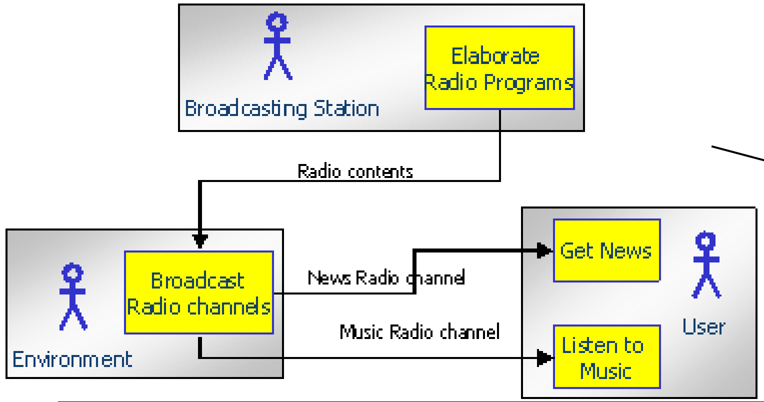
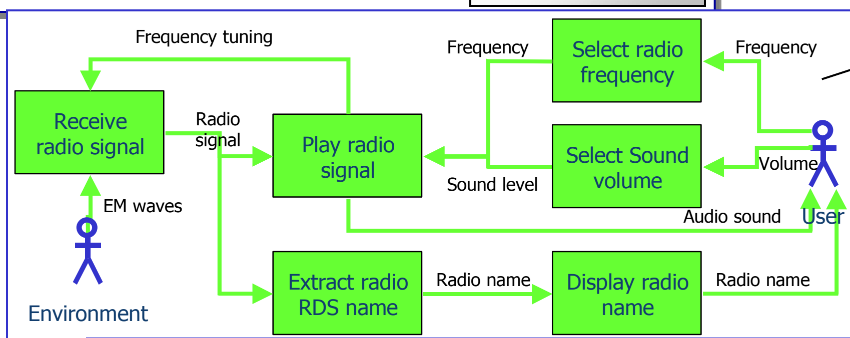
ARCADIA Concepts

Examples

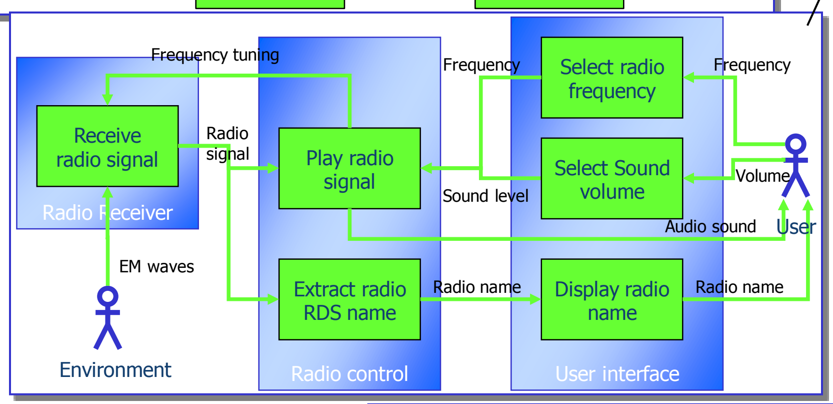
ARCADIA Concepts: Radio Set Example



1. What **the users** of the system need to accomplish

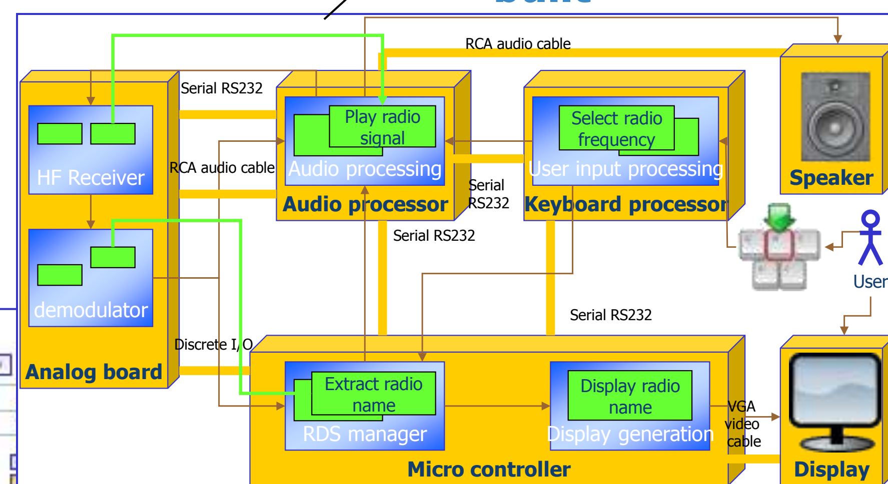


2. What **the system** has to accomplish for the users

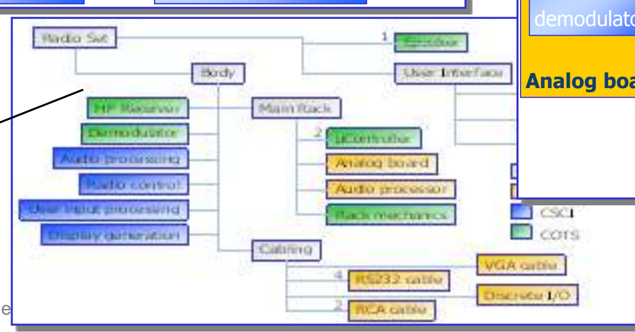


3. How the system **will work** so as to fulfil expectations

4. How the system will be **developed & built**



5. **What is expected** from each designer / sub-contractor



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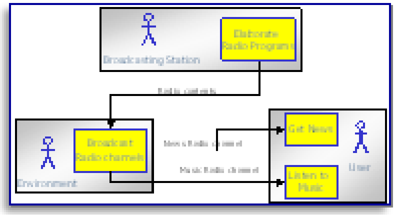

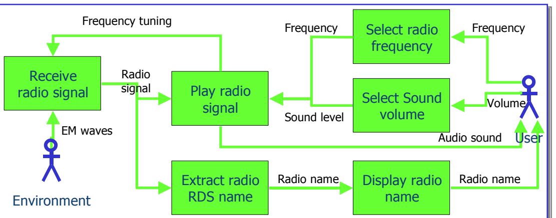

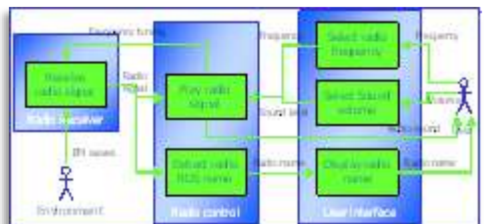

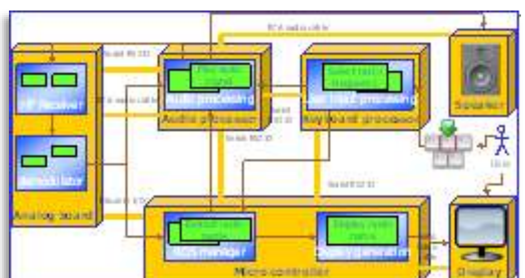

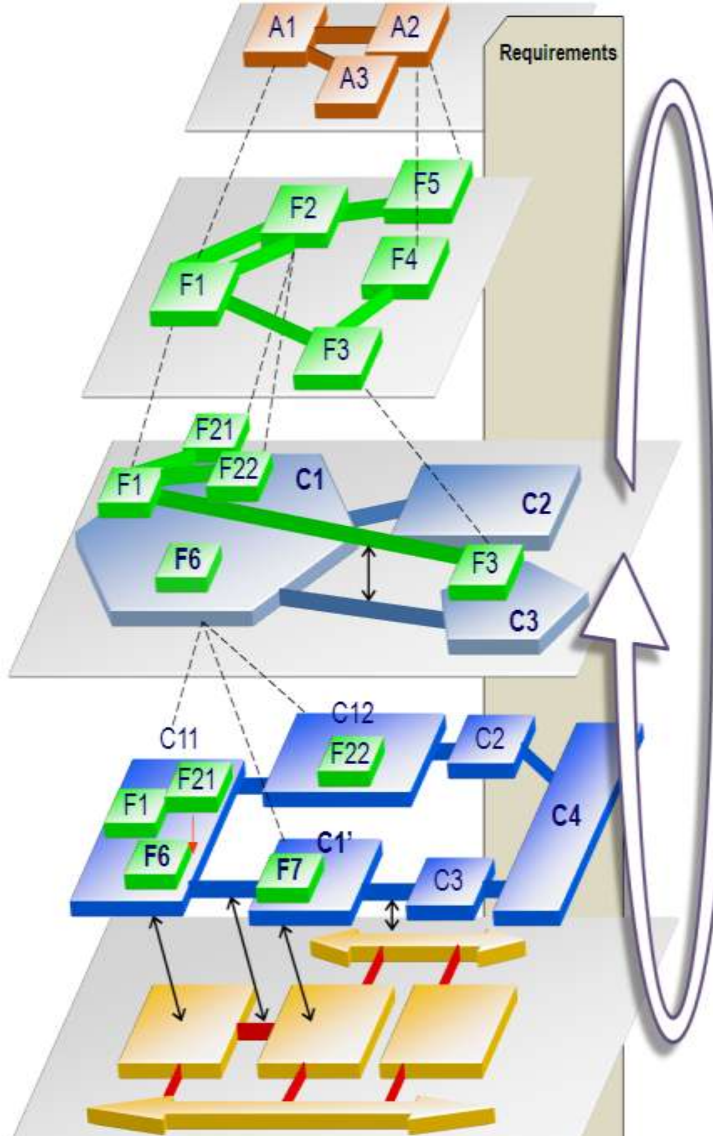

EPBS – End Product Breakdown Structure

User Need

System Need

Notional Solution

Final Solution

Sub-contractors input

An Example of Modelling & Early Validation: In-Flight Entertainment System

Playing videos on demand
Listening to music
Surfing the web
Gaming…

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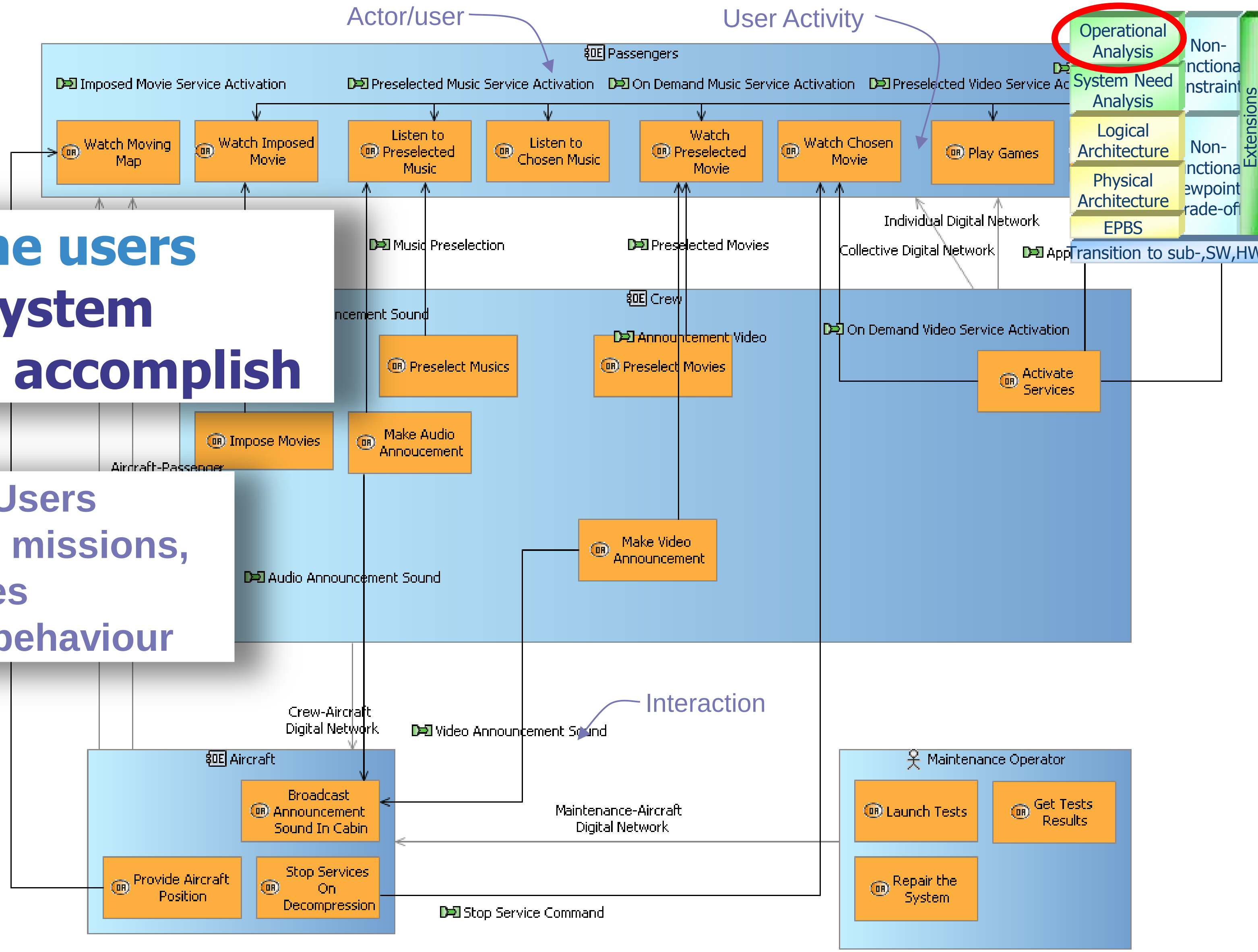
Operational Analysis: Example

What the users of the system need to accomplish

Actors & Users
Activities, missions, capabilities
Dynamic behaviour



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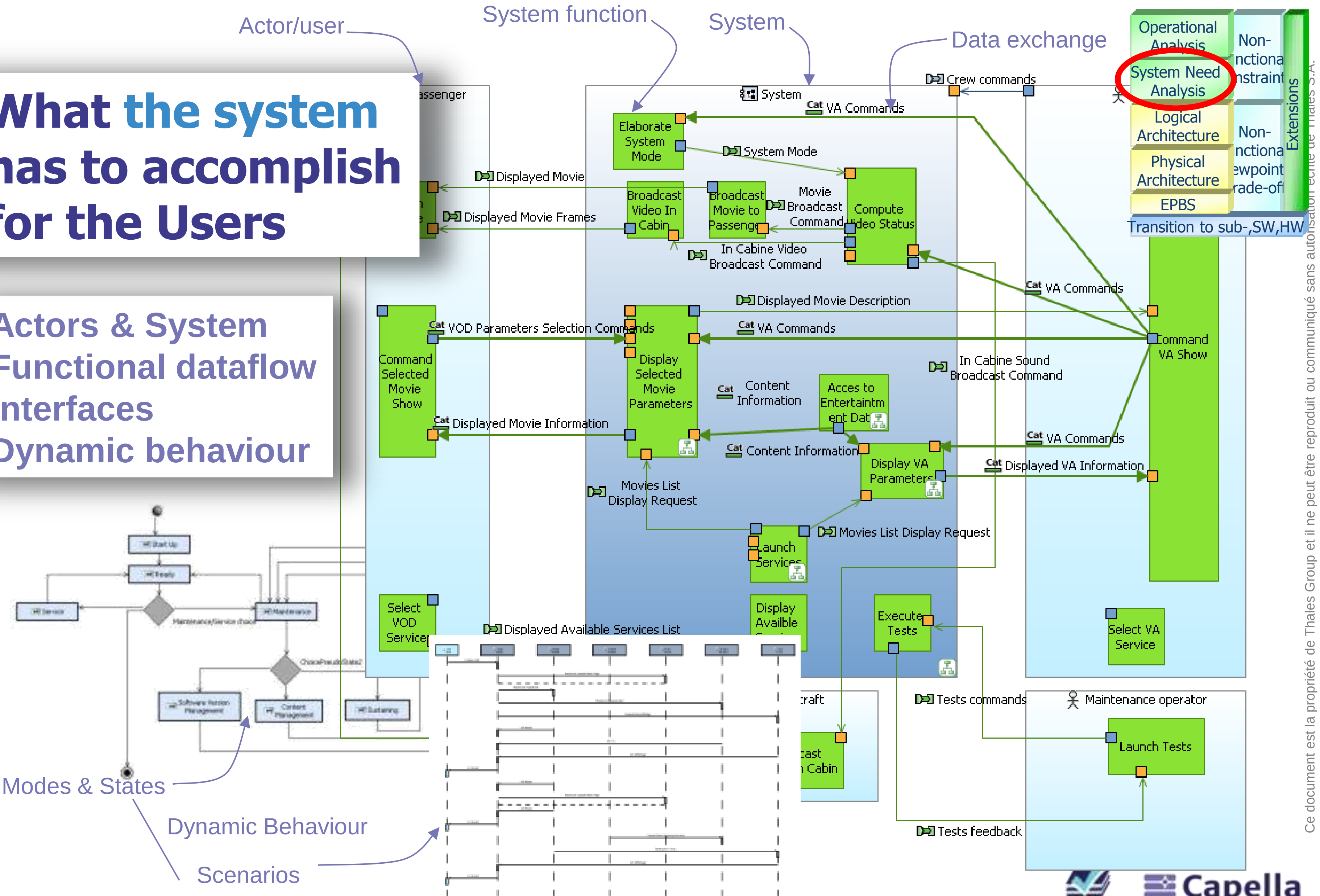
Functional Need Analysis - Example

What the system has to accomplish for the Users

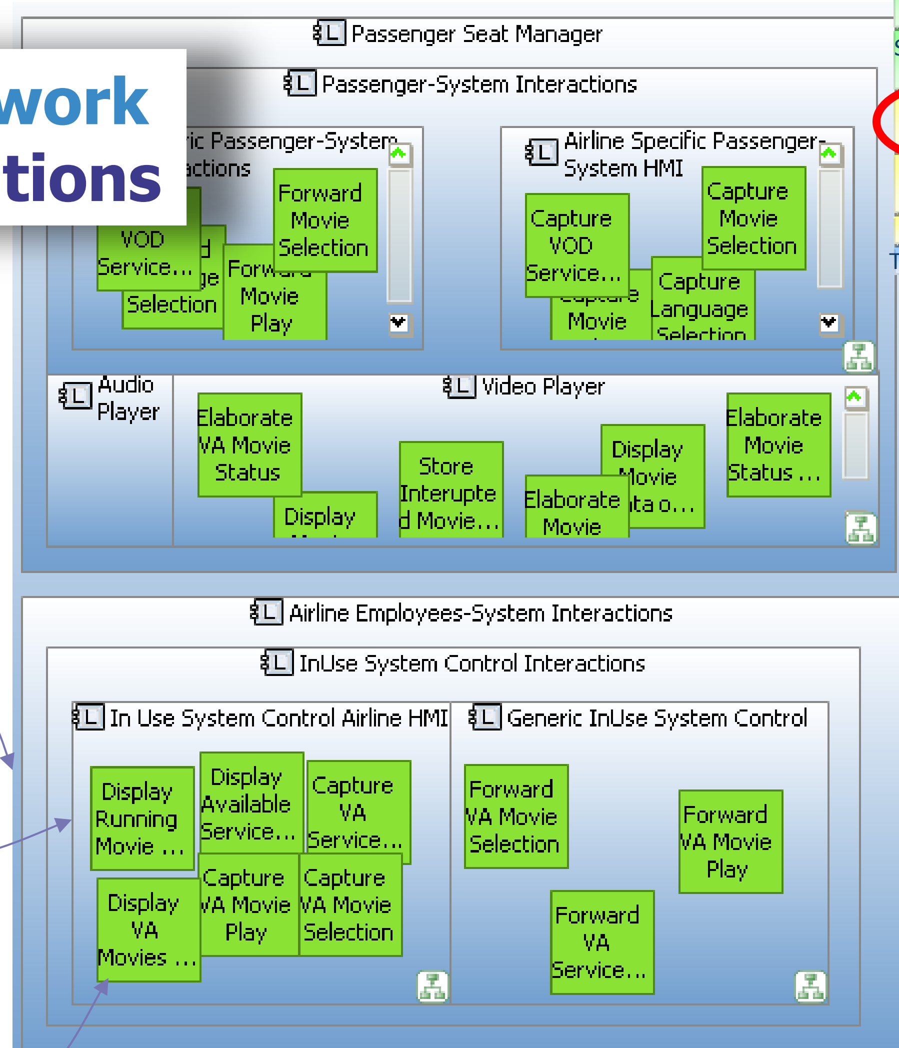
Actors & System Functional dataflow interfaces Dynamic behaviour

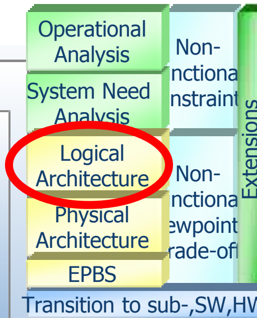


Logical Architecture - Example

How the system will work so as to fulfil expectations

Functional allocation to components
First trade-off analysis
(see multi-viewpoints)





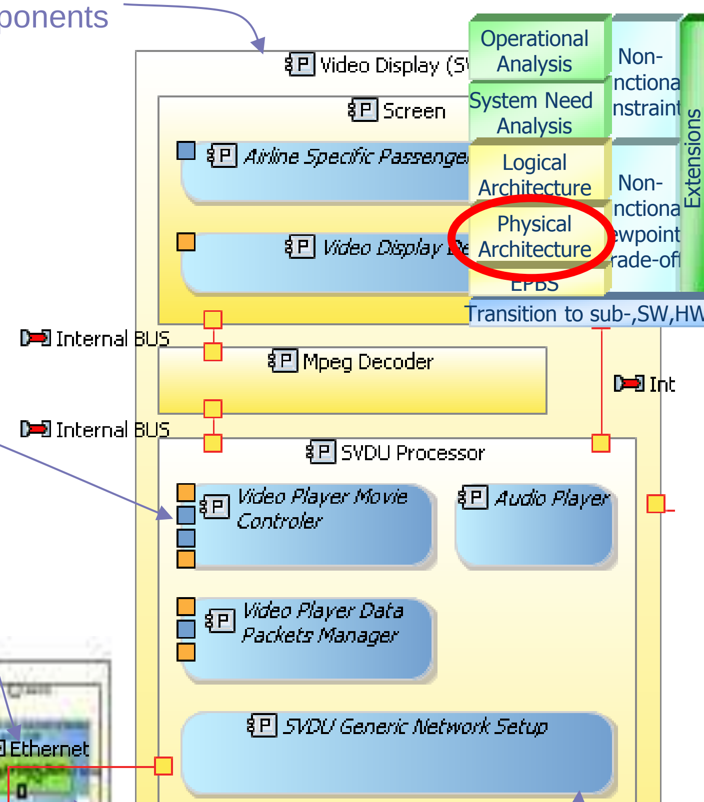
System component

Sub-components

Allocated functions

Physical Architecture

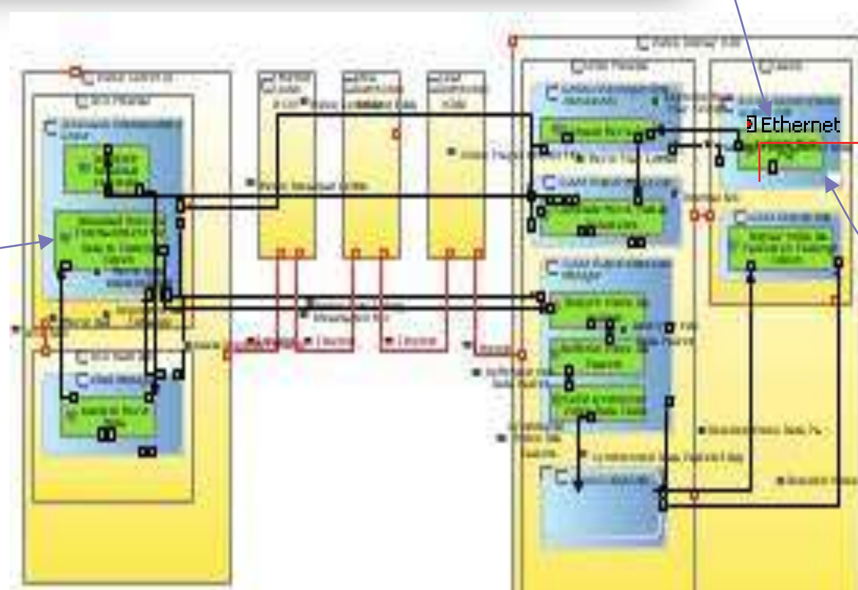
Implementation components
(e.g. hardware)



How the system will be developed and built

- Software Vs Hardware allocation
- Functional allocation check
- Interface definition/justification
- Trade-off analysis (see multi-viewpoints)

Allocated functions

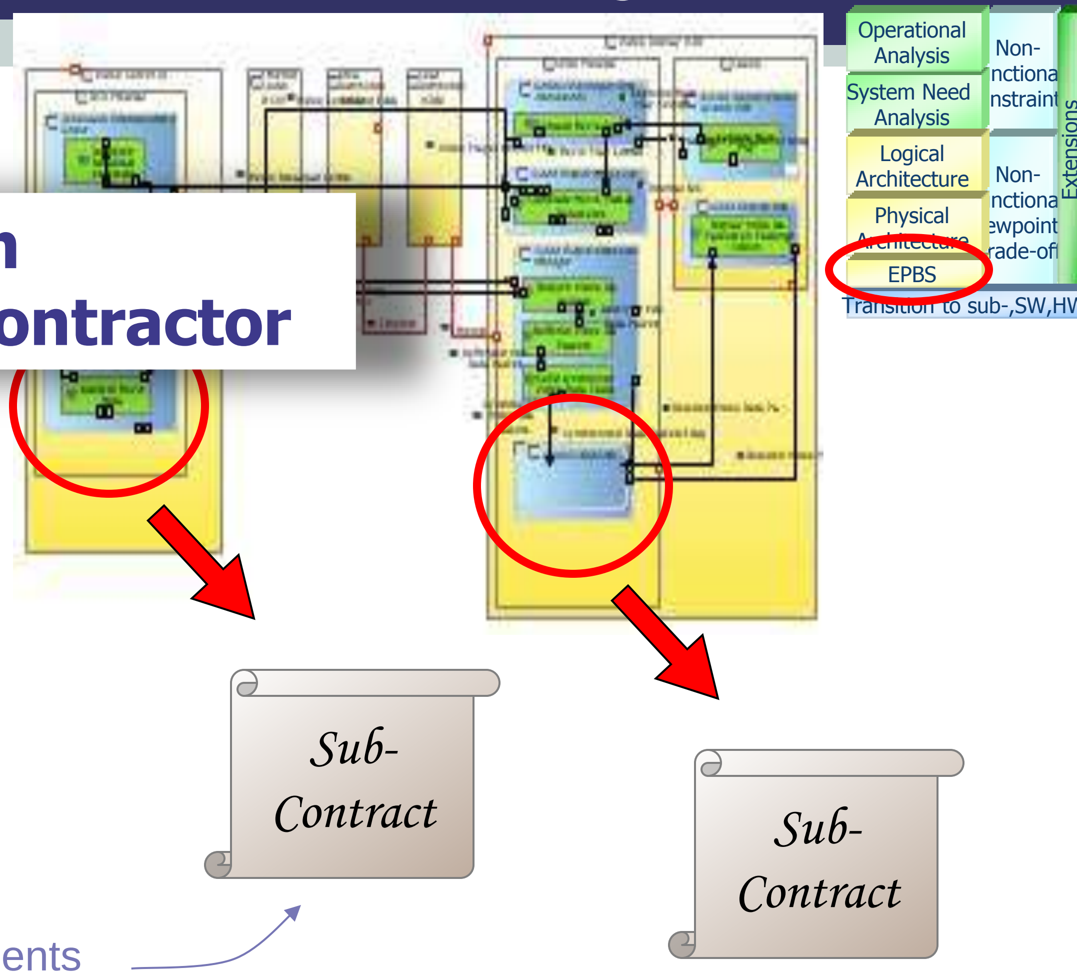


Behavioural components
(e.g. software)

EPBS: End Product Breakdown Structure

EPBS and Components Integration Contracts

What is expected from each designer / sub-contractor



- Requirements
- Interfaces
- Operational use case scenarios
- Expected behaviour & functional dataflow
- Allocated non-functional constraints (latency, criticality…)
- Allowed implementation resources
- …

EPBS: End Product Breakdown Structure

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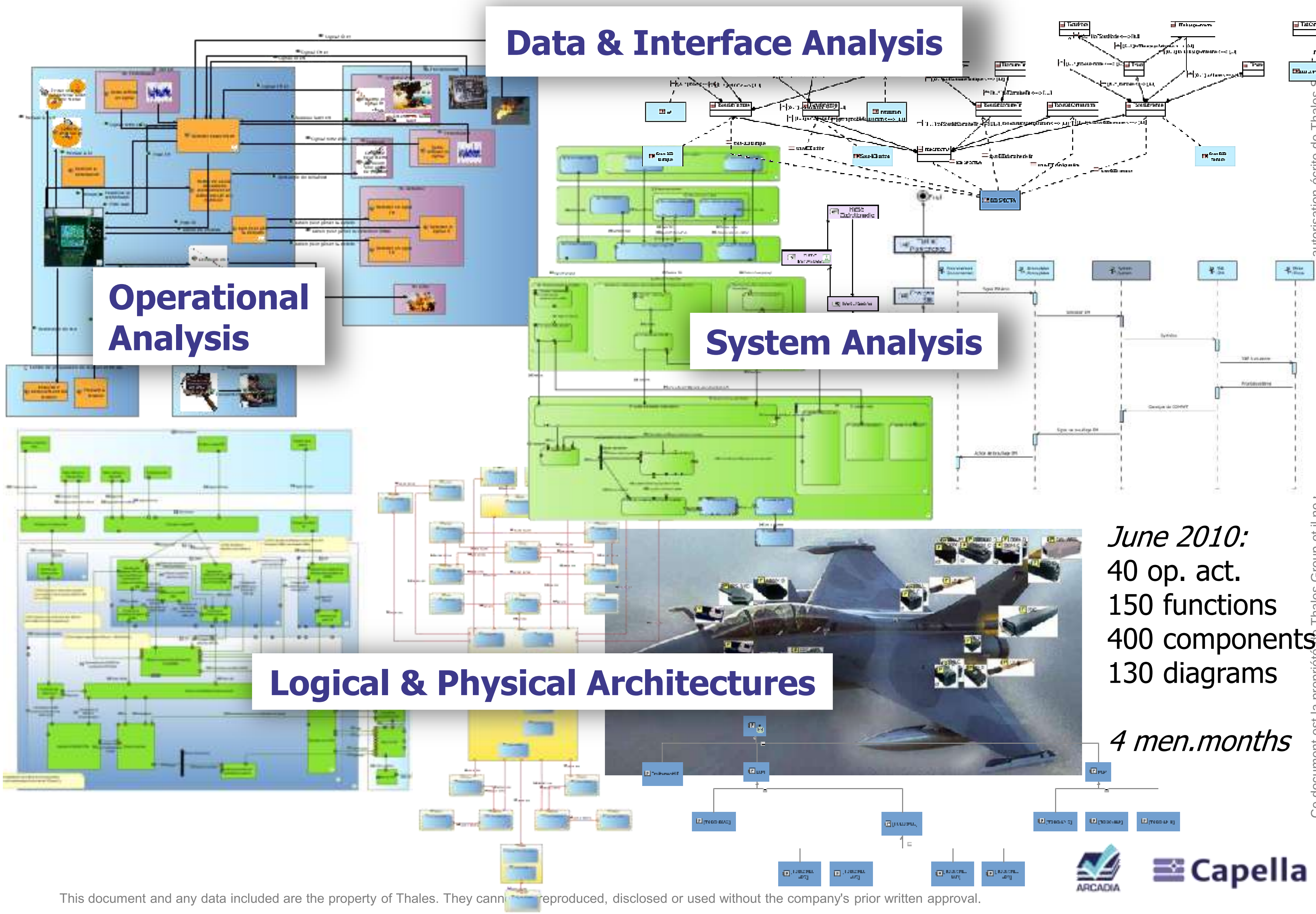
Self-Protection System Example (Bird Eye)



June 2010:
40 op. act.
150 functions
400 components
130 diagrams

4 men.months

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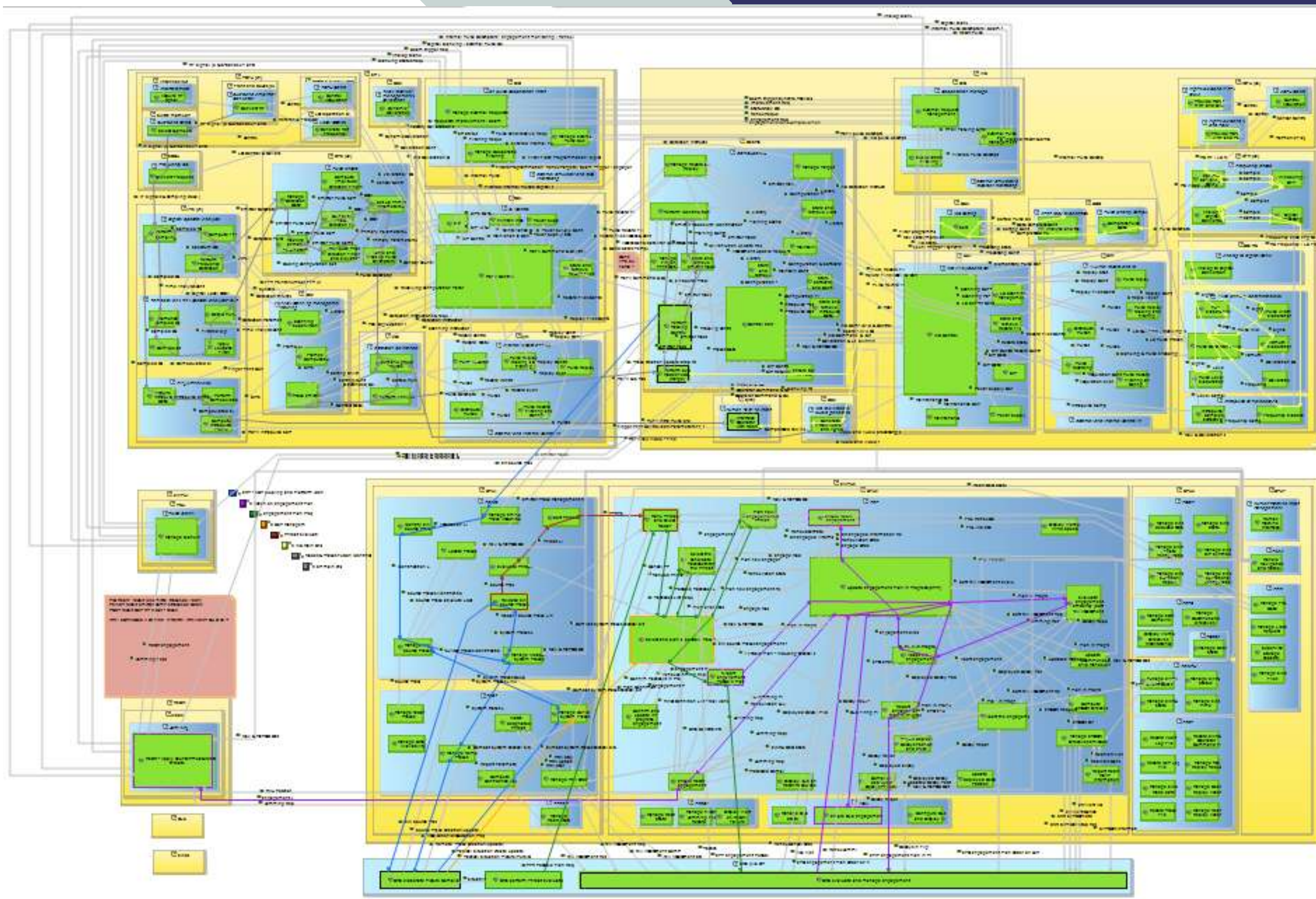
Exampe of Physical Architecture Overview



ARCADIA Concepts

Introduction to Arcadia engineering steps

Concepts, Shared Assets and Justification Links

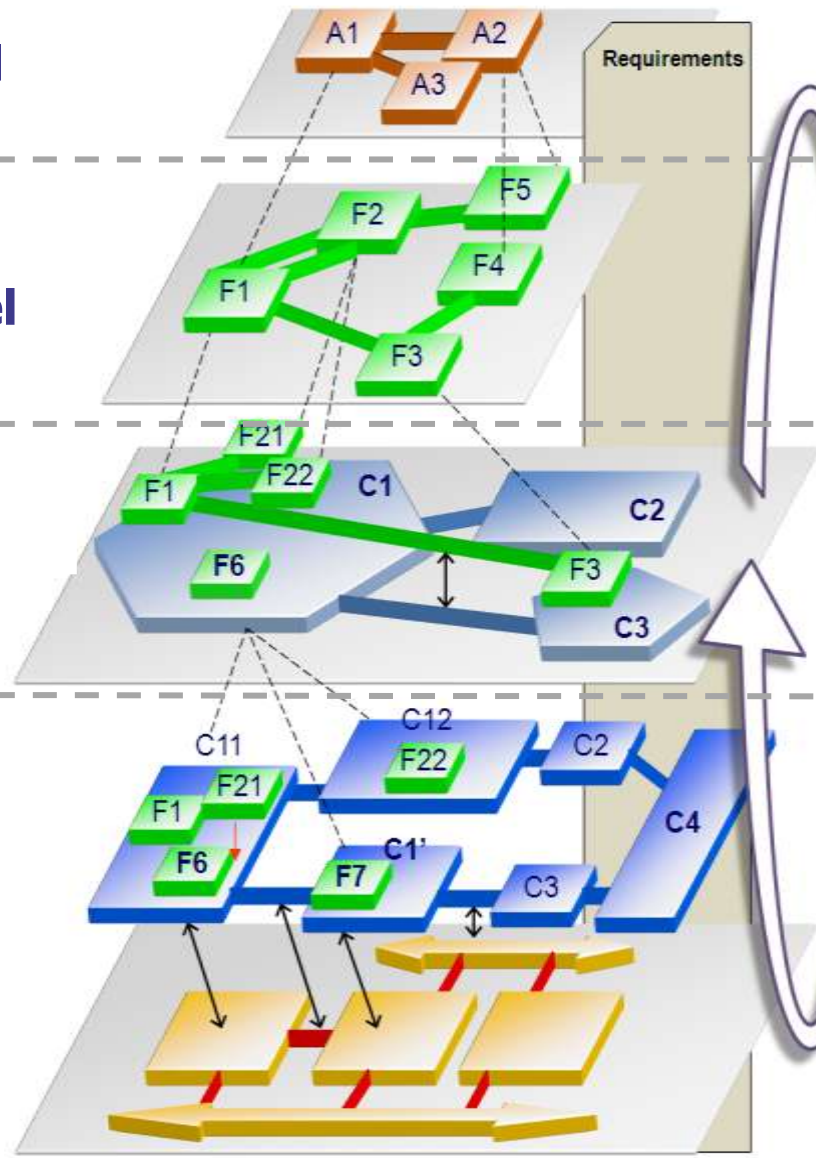
Operational Analysis Model

System Functional and Non-Functional Need Model

Logical Architecture Model

Physical Architecture Model

Product Breakdown



Activities (and Entities) layer

Functions layer

Functions layer

« Logical » component layer

Functions layer

« Behavioural » component layer

« Implementation » component layer

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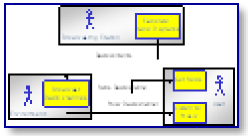
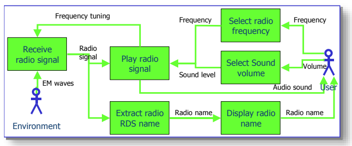
Behaviour Description Means

Operational Analysis

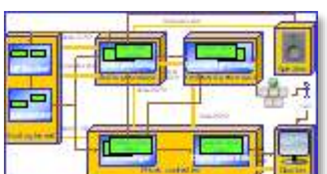


System Functional & NF Need

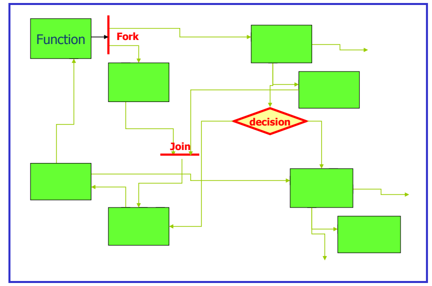


Logical Architecture

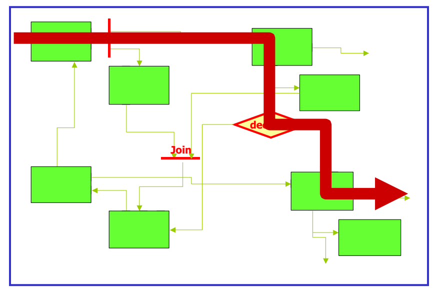
Physical Architecture



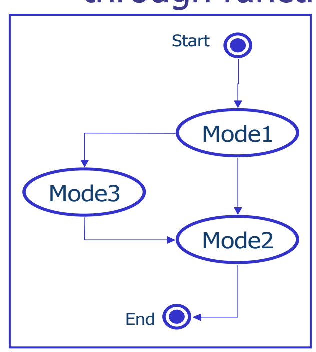
Product Breakdown



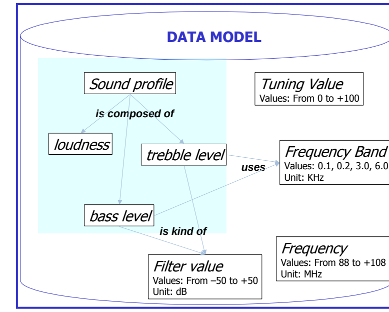
Dataflow: Functions, op. activities interactions & exchanges



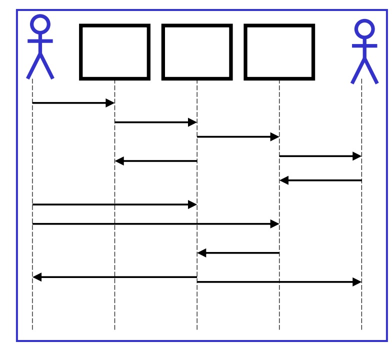
Functional chains, Operational processes through functions & op. activities



Modes & states: Of actors, system, components



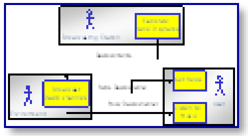
Data model: Dataflow & scenario contents; Definition & justification of interfaces



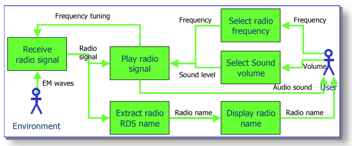
Scenarios: Actors, system, components interactions & exchanges

Behaviour Description Means

Operational Analysis

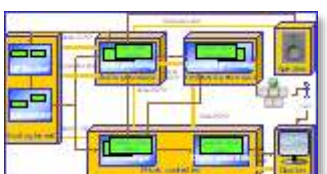


System Functional & NF Need

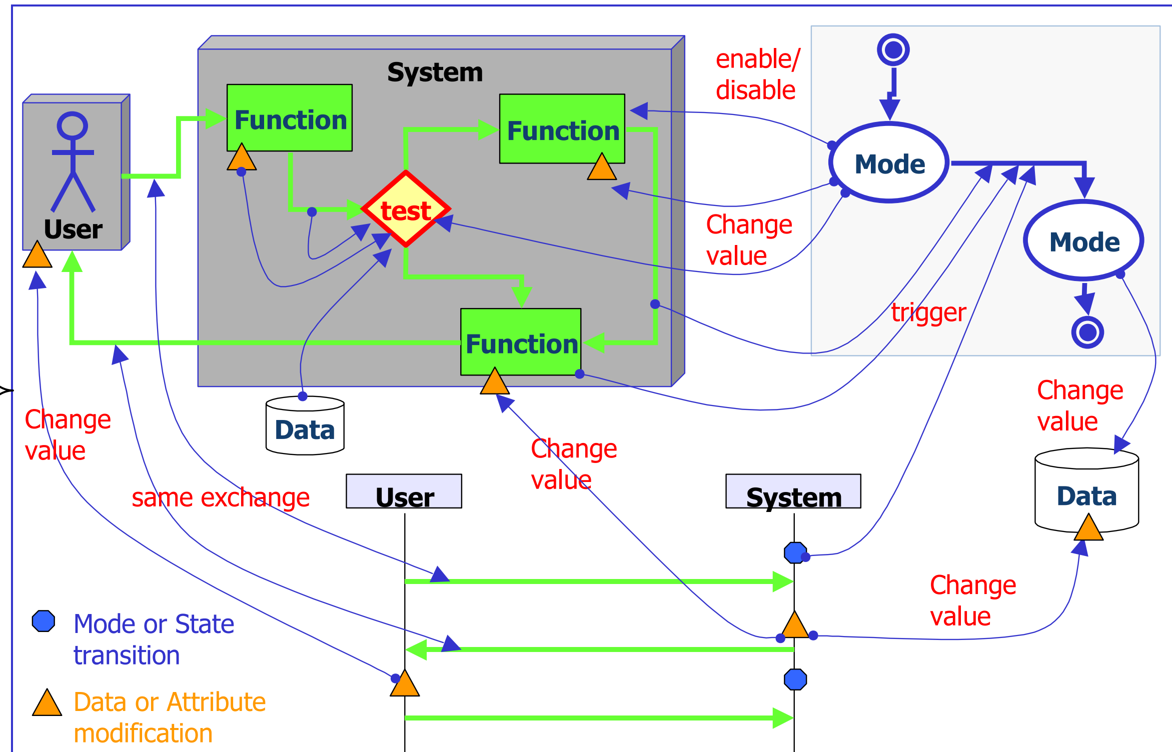


Logical Architecture

Physical Architecture

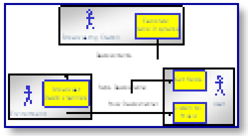


Product Breakdown

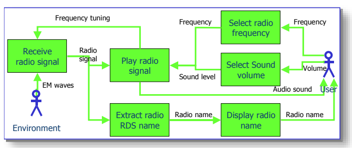


Architecture Description Means

Operational Analysis

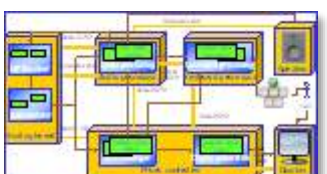


System Functional & NF Need

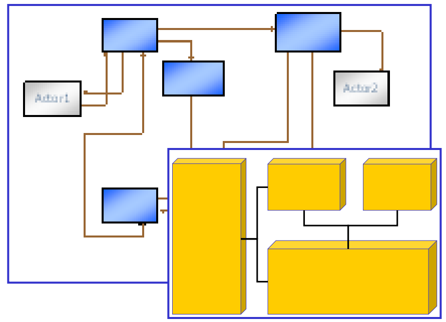


Logical Architecture

Physical Architecture

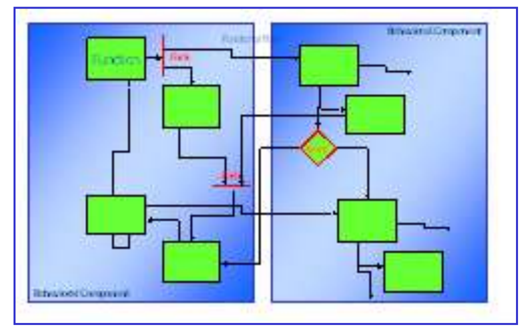


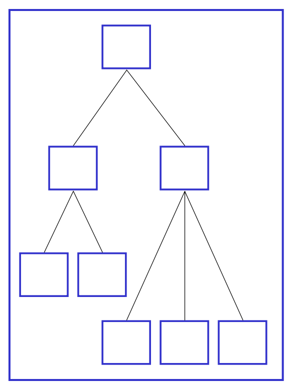
Product Breakdown



Dataflow: Functions, op. activities interactions & exchanges

Component wiring: All kinds of components





Breakdown: Of all concepts

Allocation:

- op. activities to actors,
- functions to components,
- behav. Components to impl. Components
- dataflows to interfaces,
- elements to configuration items

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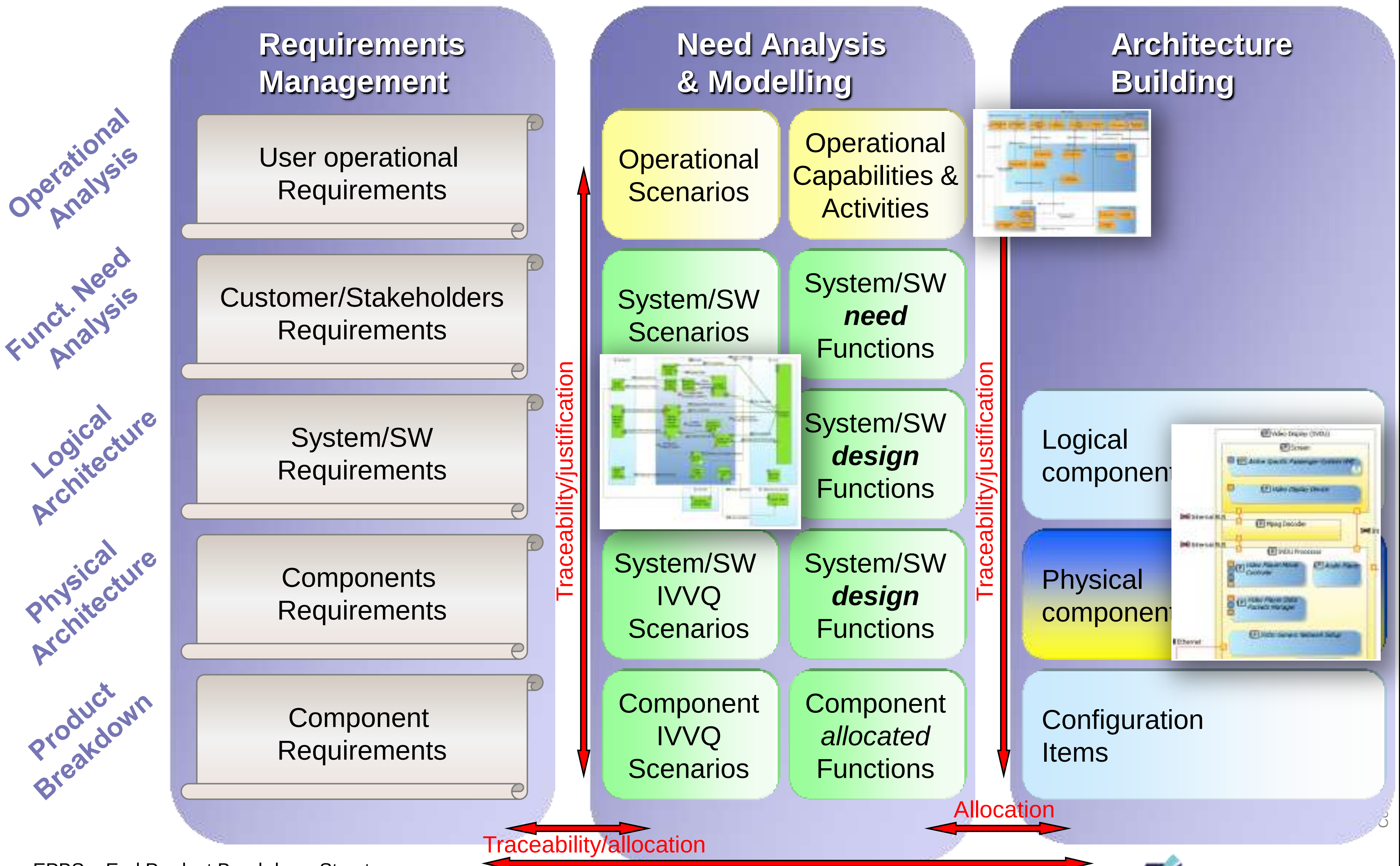
The Engineering Triptych, ‘Three Legs Better Than One’

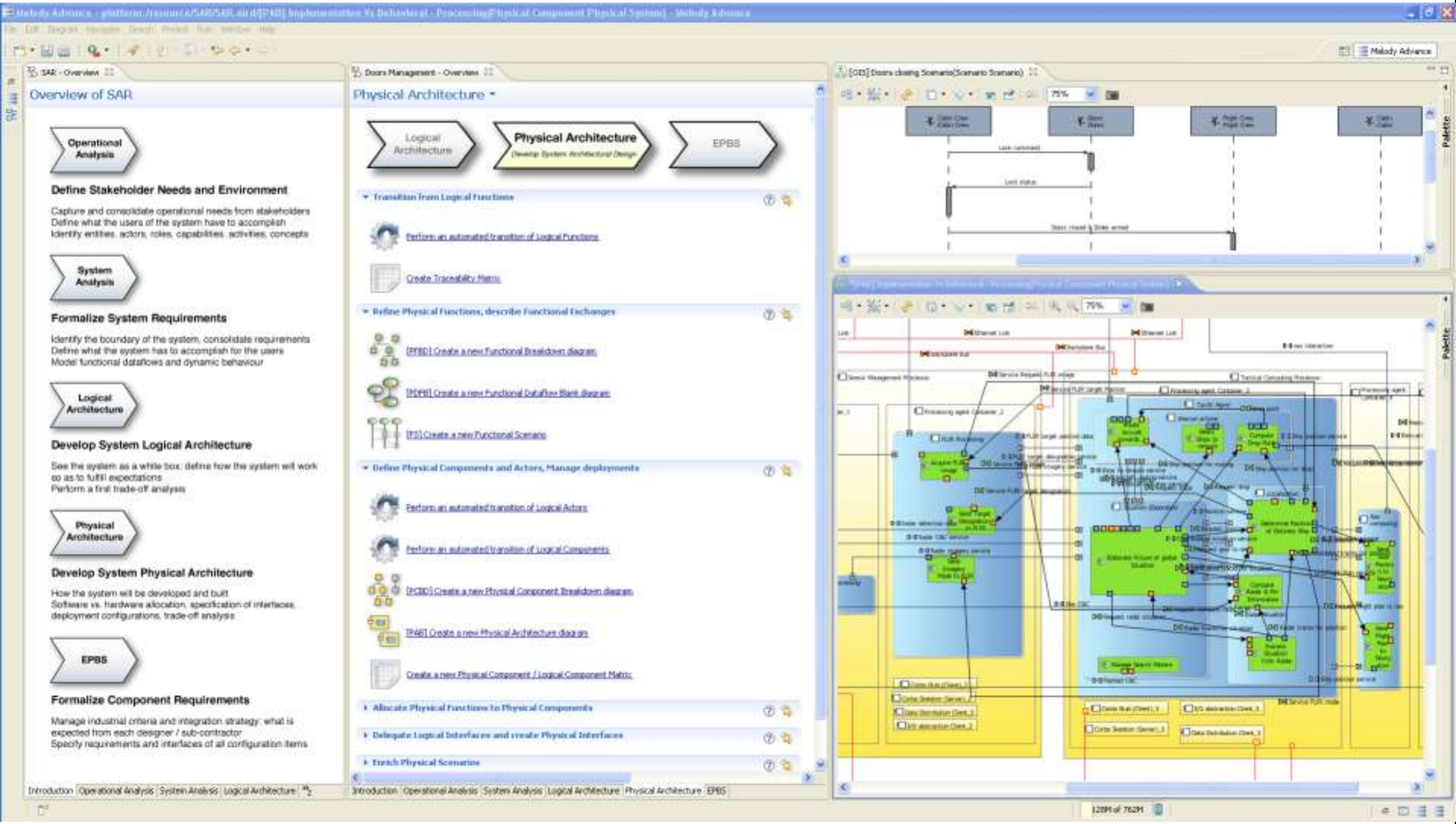


EPBS – End Product Breakdown Structure

ARCADIA Concepts

Capella workbench, a tooled supporting the method

ARCADIA Support by Capella Workbench (1/2)



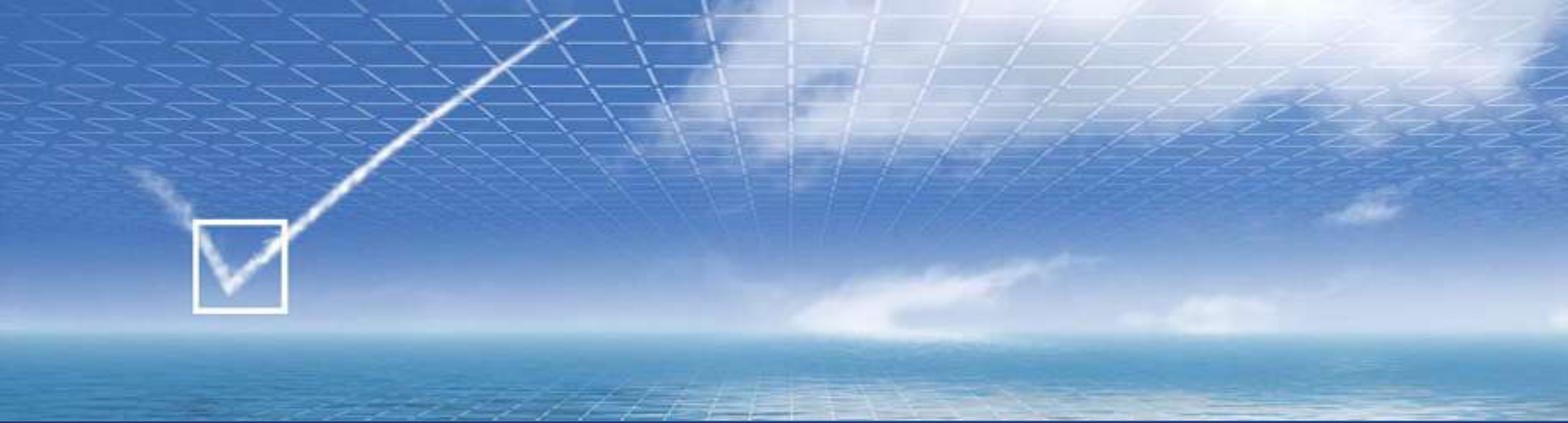
ARCADIA Support by Capella Workbench (2/2)

Capella solves some of the weaknesses of COTS* or OSS*:

- ARCADIA Method support & **guidance** for modelling
  - Method Steps, encyclopaedia, rules, diagrams…
- **User-oriented** Semantics
  - Engineer concepts rather than abstract/profiled language
- Support for « modelling **in the large** »
  - Performance on large models, ergonomics, modelling aids…
- Support for **viewpoint extensions**, modelling & analysis
  - Model extensions, diagrams extensions, viewpoint management…
- « Semantic » Import/export capabilities (excel, SysML, AF, …)

- Yet ARCADIA is also deployed using other tools
  - Excel/Access, Rhapsody, System Architect/DoDAF…
  - with reduced capabilities, however

* COTS: Commercial Off The Shelf
* OSS: Open Source Software



ARCADIA Concepts

Operational Analysis

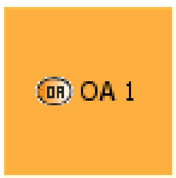
Operational Analysis - Overview

- Focuses on analysing the **needs and goals, expected missions & activities**

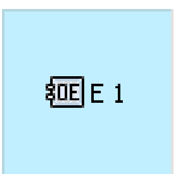
- Is expected to ensure **good adequacy of System definition with regards to its real operational use** – and define IVVQ conditions

- Outputs : Operational Needs Analysis
  - Needs, in terms of actors/users,
  - Operational capabilities and activities,
  - Operational use scenarios (dimensioning parameters, operational constraints including safety, security, system life cycle….)

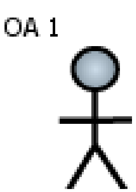
- Operational Capability
  - A capability is the ability of an organisation to provide a service that supports the achievement of high-level operational goals.



- Operational Activity
  - Process step or function performed toward achieving some objective, by entities that could necessitate to use the future system for this
  - e.g. Control traffic, go along a place, detect a threat

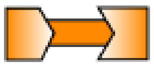


- Operational Entity
  - An operational Entity is a real world entity (other system, device, group or organisation…), interacting with the system (or software, equipment, hardware…) under study, or with its users



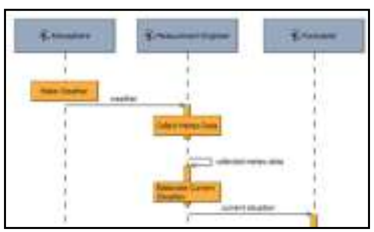
- Operational Actor
  - An actor is a [usually human] non decomposable operational Entity

Operational Analysis: Main Concepts (2/2)



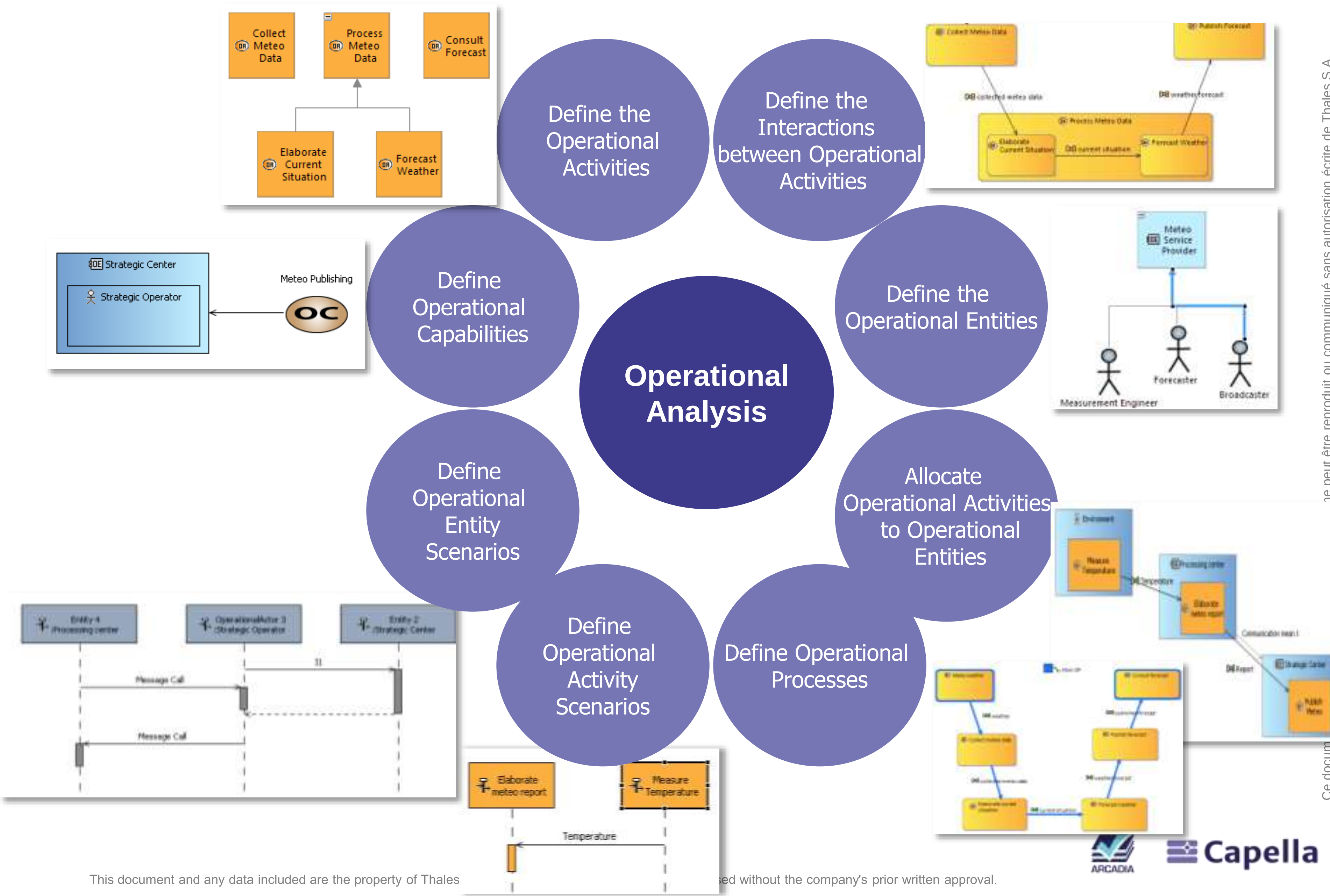
- Operational Interaction
  - Set of Operational services invocations or flows exchanged between Operational Activities, (e.g. Operational Interactions can be composed of Operational data, events...).

- Operational Process
  - A logical organization of Interactions and Activities to fulfil an Operational Capability



- Operational Scenario
  - A scenario describes the behaviour of a given Operational Capability

Operational Analysis Workflow and Main Diagrams



Capella

ARCADIA Concepts

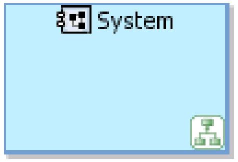
System Need Analysis

System Analysis - Overview

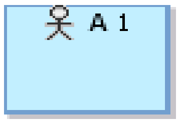
- Define **how the system can satisfy the former operational needs**:
  - System functions to be supported & related exchanges
  - Non functional constraints (safety, security…)
  - Performances allocated to system functional chains
  - Role sharing and interactions between system and operators

- **Checks for feasibility** (including cost, schedule and technology readiness) of customer requirements

- Outputs: System Functional Analysis description
  - Interoperability and interaction with the users and external systems (functions, exchanges plus non-functional constraints), and system requirements



- **System**
  - An organized set of elements functioning as a unit.
  - An aggregation of end products and enabling products to achieve a given purpose.



- **System Actor**
  - External actor interacting with the system via its interfaces

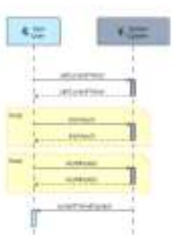
- **System Mission**
  - A mission describes a major functionality of the system from a very high level point of view. It is a reason why the system is developed.
  - high-level operational goal

- **System Capability**
  - A capability is the ability of a system to provide a service that supports the achievement of high-level operational goals

- **System Function**
  - Function at System level
  - A function is an action, an operation or a service fulfilled by the system or by an actor when interacting with the system
  - e.g. 'measure the altitude', 'provide the position'

System Analysis: Main Concepts (2/2)

- Exchange and Port
  - An Exchange is an interaction between some entities such as actors, the system, functions or components, which is likely to influence their behaviour.
  - e.g. tuning frequency, radio selection command…
  - The connection point of an exchange on an entity is called a port.
- Functional Exchange
  - Piece of interaction between functions that is composed of data, events, signals, etc. A Flow Port is an interaction point between a Function and its environment that supports Exchanges with other ports

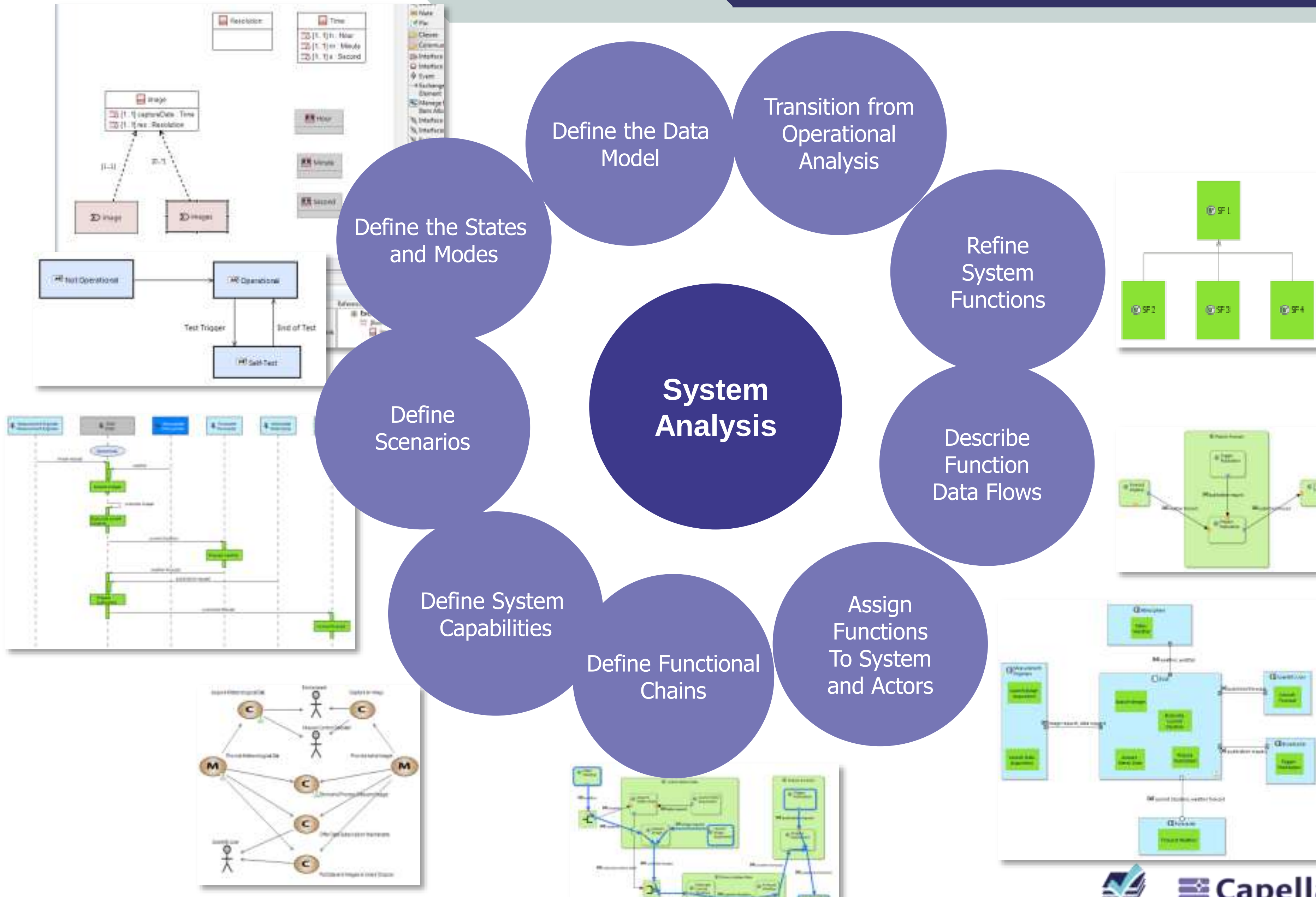


- Scenario
  - A scenario describes the behaviour of the system in a given Capability.
  - Scenarios permit to specify the dynamical behaviour of the system by showing interaction sequences performed by the actors and by the system

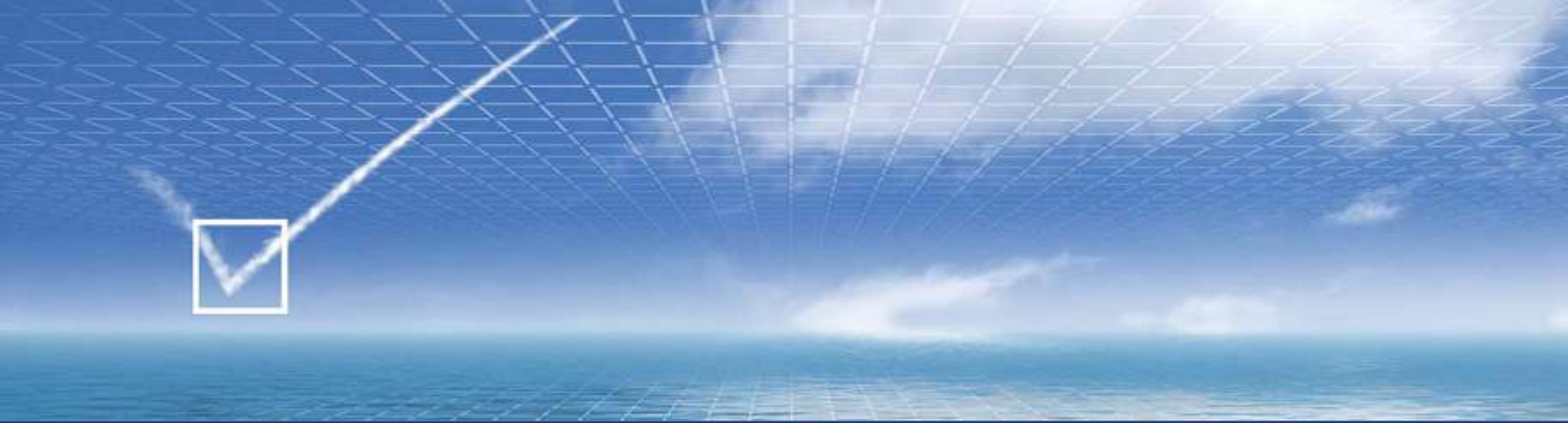
- State
  - a physical and operational environment condition

- Mode
  - a type of operation in a given state of the system, or the performance level within a state

System Analysis Workflow and Main Diagrams



Capella



ARCADIA Concepts

Logical Architecture

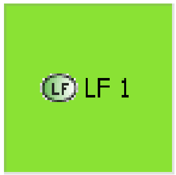
Logical Architecture - Overview

- Intends to identify the **system components, their contents, relationships and properties, excluding implementation or technical/technological issues**. This constitutes the system logical architecture.

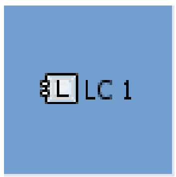
- All major [non-functional] constraints (safety, security, performance, IVV…) are taken into account so as to find the **best compromise** between them.

- Outputs : selected logical architecture:
  - Components & interfaces definition, including formalisation of all viewpoints and the way they are taken into account in the components design.
  - Links with requirements and operational scenarios are also produced

Logical Architecture Design: Managed Entities

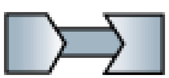


- Logical Function
  - Function applied at Logical level



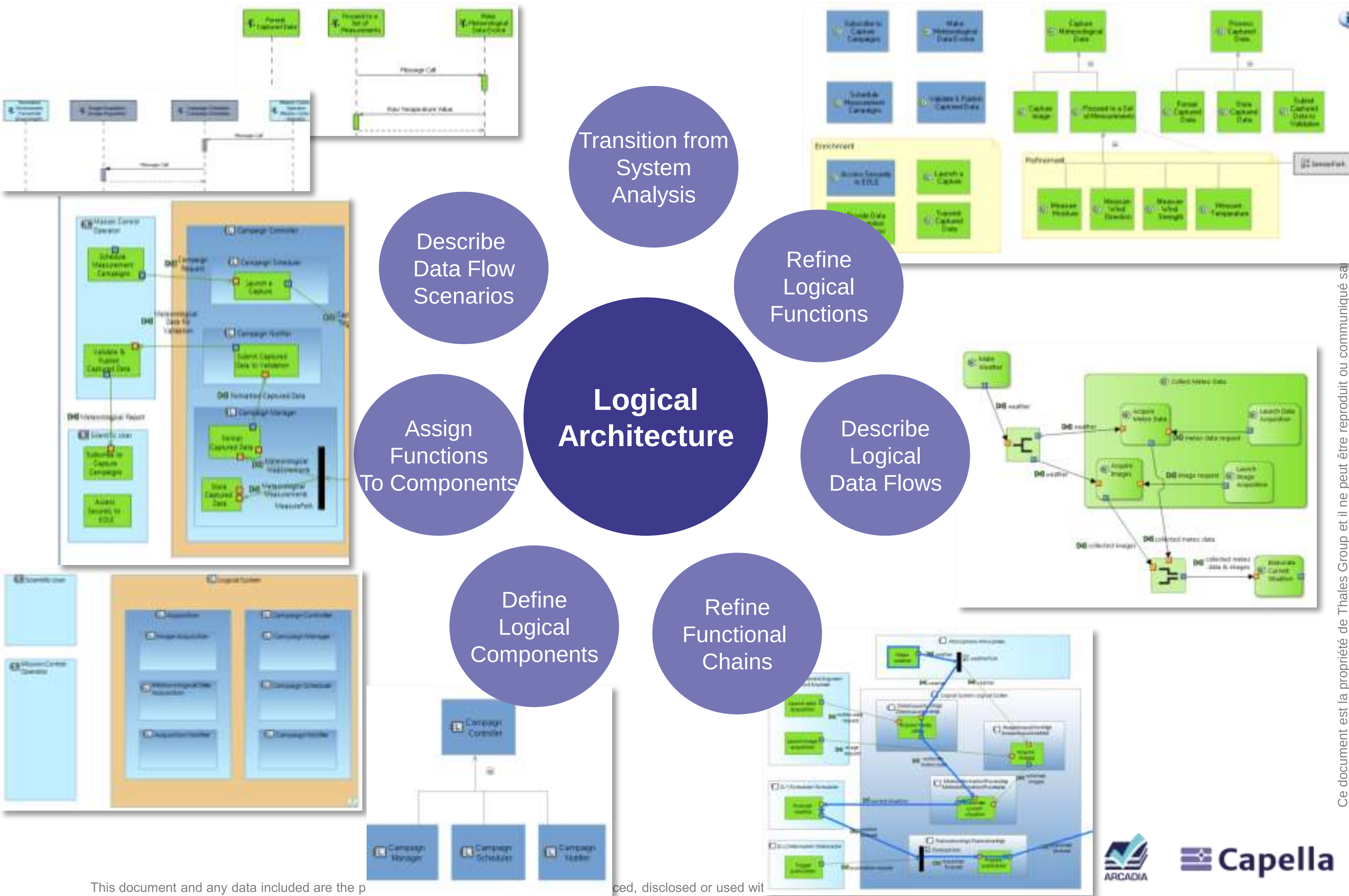
- Logical Component
  - Logical Components are the artefacts enabling a notional decomposition of the system as a "white box", independently from any technological solutions, but dealing with major system decomposition constraints
  - Logical components are identified according to logical abstractions (i.e. functional grouping, logical interfaces)

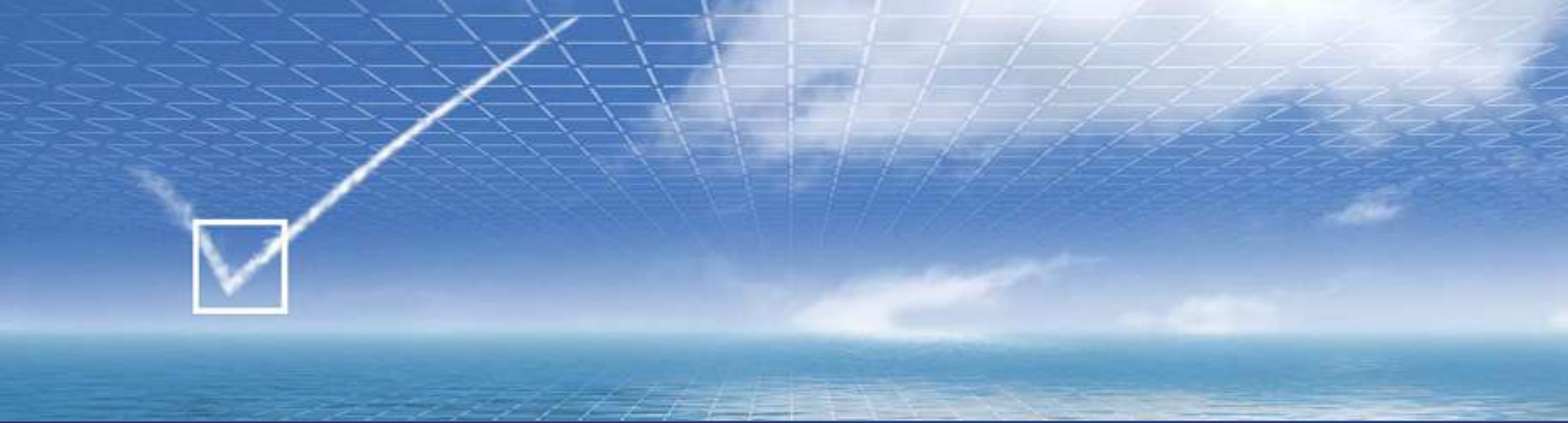
- Functional Exchange
  - Piece of interaction between functions that is composed of data, events, signals, etc. A Flow Port is an interaction point between a Function and its environment that supports Exchanges with other ports



- Component Exchange
  - Represent the interactions between Logical Components

Logical Architecture Workflow and Main Diagrams





ARCADIA Concepts

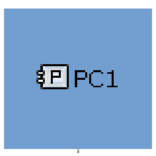
Physical Architecture

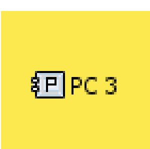
Physical Architecture - Overview

- Intends to identify the system components, their contents, relationships and properties, including implementation or technical/technological issues
- **Introduces rationalisation, architectural patterns, new technical services and components**
- Makes the logical architecture evolve according to implementation, technical & technological constraints & choices (at this level of engineering)
- The same 'Viewpoints-driven' method as for logical architecture design is used for physical architecture definition
- Outputs : selected Physical Architecture:
  - Physical Components, including formalisation of all viewpoints and the way they are taken into account in the components design
  - Links with requirements and operational scenarios

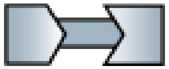
Physical Architecture Design: Main Concepts (1/2)

- Physical Function
  - Function applied at physical level
- Physical Component
  - Physical Components are the artefacts enabling to describe physical decomposition of the system to satisfy the logical architecture identified at the upper abstraction level. Physical components are identified according to physical rationale (i.e. components reuse, available COTS, non functional constraints...).
  - Two natures of components :
    - Behaviour
      - physical component in charge of implementing / realising part of the functions allocated to the system
      - e.g. operational software, radar antenna, …
    - Node or implementation
      - material physical component, resource embedding some behavioural components, and necessary to their expected behaviour
      - e.g. motherboard, units of memory, middleware's and operating systems …





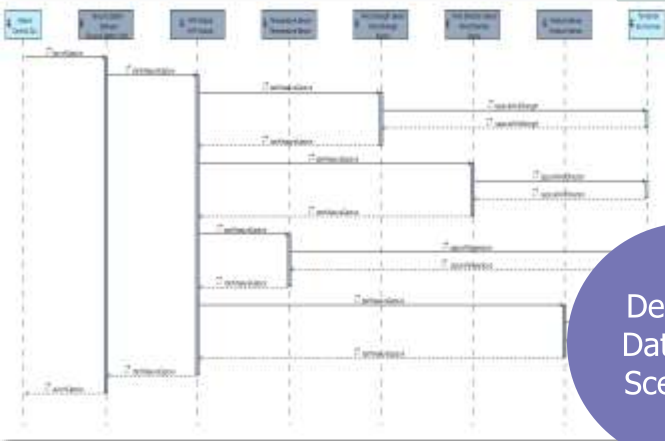
Physical Architecture Design: Main Concepts (2/2)

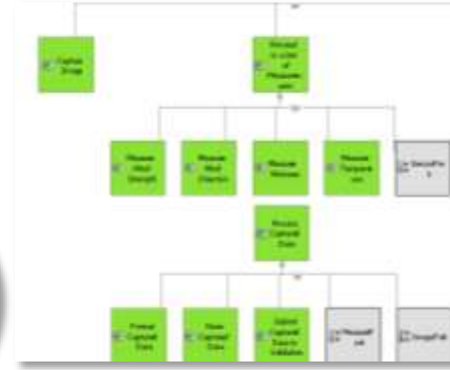


- Component Exchanges are meant to be used between Behaviour Components.
  - They are identical to the Component Exchanges of the System Analysis and the Logical Architecture

- Physical Links are non-oriented material connections between Node Components, through Physical Ports.
  - They realize Component Exchanges, and appear in red on the diagram

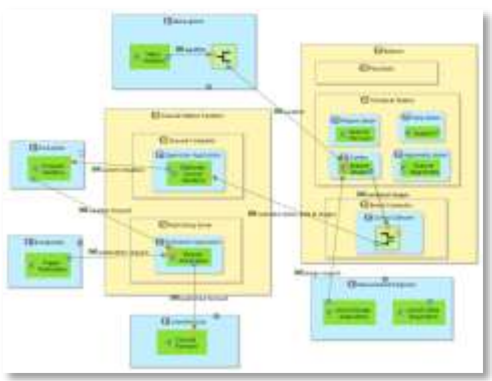
Physical Architecture Workflow and Main Diagrams

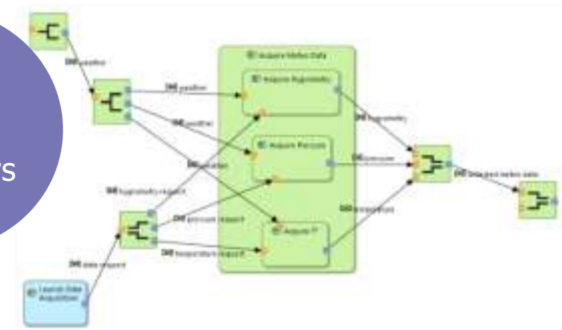


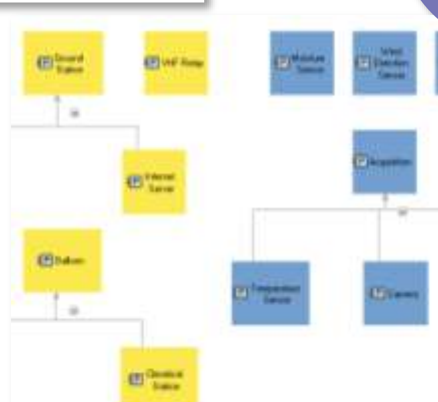


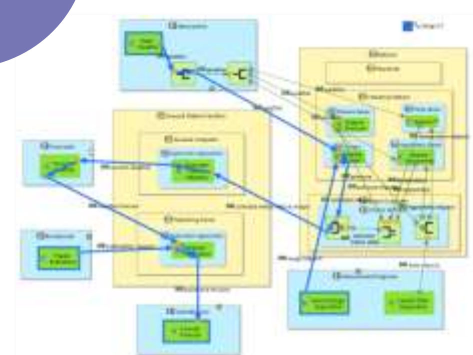
Physical Architecture

- Transition from Logical Architecture
- Refine Physical Functions
- Describe Physical Data Flows
- Refine Functional Chains
- Define Physical Components
- Assign Functions To Components
- Describe Data Flow Scenarios









ARCADIA Concepts

End-Product Breakdown Structure

Define the End-Product Breakdown Structure

- At this step, **Configuration Items (CI) contents are to be defined in order to build a Product Breakdown Structure (PBS)**
  - By grouping various former components in a bigger CI easier to manage,
  - Or by federating various similar components in a single implementation CI that will be instantiated multiple times at deployment
- Defines the "final" architecture of the system at this level of engineering, ready to develop (by lower engineering levels)
- Allocation of requirements on configuration items
- Consideration of industrial & subcontracting constraints
- Outputs
  - EPBS

ARCADIA Concepts

Focus on Functional Analysis, different engineering approaches

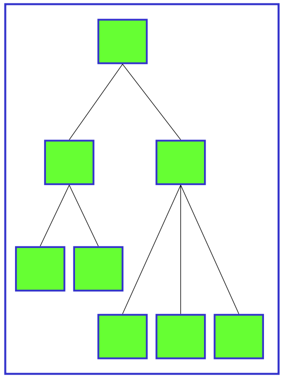
Different Ways to Build a Functional Analysis: Examples

Top-down functional breakdown:

- Describe need as a few interrelated high level functions
- Refine each function, and associated exchanges
- Hierarchical, recursive approach

1-

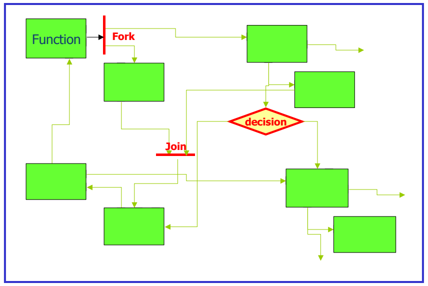
2-



Bottom-up requirement-driven:

- Often used to formalise textual requirements
- "translate" each requirement into elementary functions, exchanges, and constraints on them
- Then synthesise higher level views by grouping elementary (leaf) functions into mother functions
- And synthesise exchanges by grouping them into categories

1-



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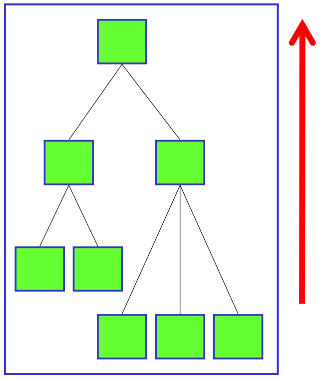
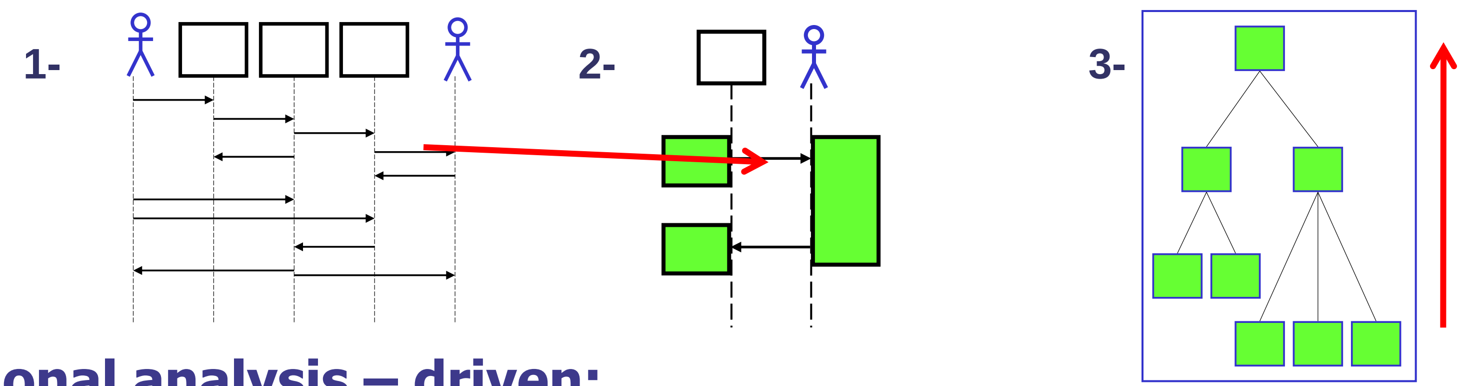


Different Ways to Build a Functional Analysis: Examples

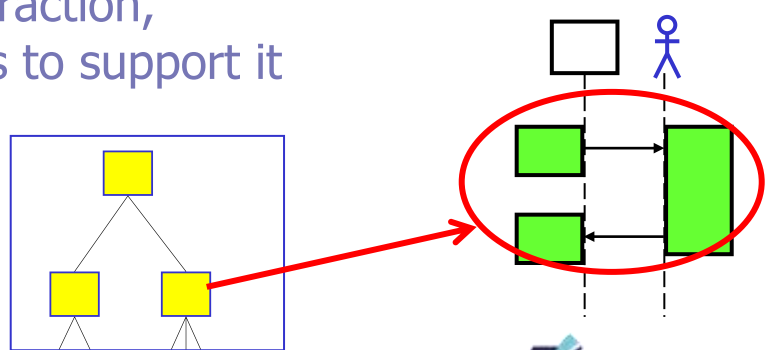
Use case - driven:

- Start building scenarios to illustrate system use & external interactions (or components and internal interactions)
- Then define functions at each end of exchanges
- Then enter a bottom-up approach to synthesise functions



Operational analysis – driven:

- For each operational activity or interaction, consider system and actor functions to support it

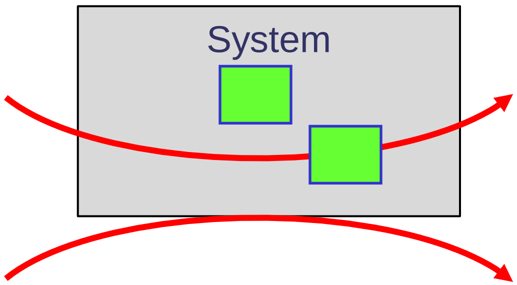


Different Ways to Build a Functional Analysis: Examples

Functional Chain – driven:

- Define major system traversal expectations
- Deduce associated functional chains, populate them with functions
- Enrich functional analysis, reusing and linking existing functions
- Then enter a bottom-up approach to synthesise functions

1-



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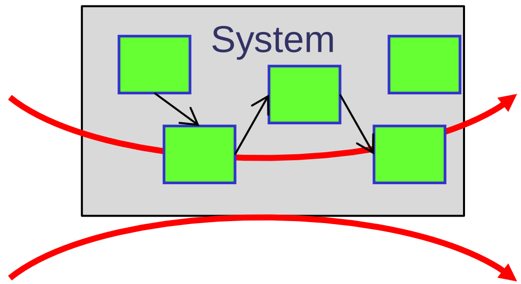

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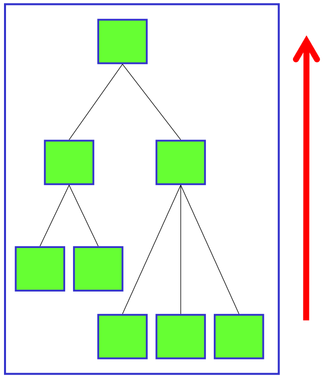


Several ways could (should?) be mixed and interleaved

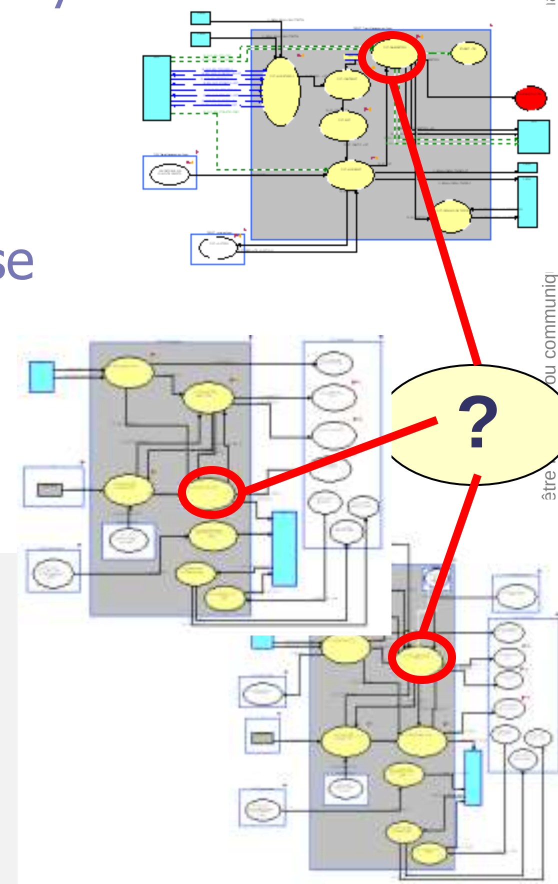
- Other ways can be considered as well

All ways should converge to the same final model contents, no matter how the building steps were ordered

What Kind of Functional Analysis?

Architecture Frameworks / IDEF0 -like?

- ☹ Uses of a same function in different diagrams may differ or oppose each other (eg, Enterprise Architect)
- ☹ No explicit definition of inputs and outputs independently from diagrams
- ☹ Poorly adapted to Reuse of functions & Use case consolidation

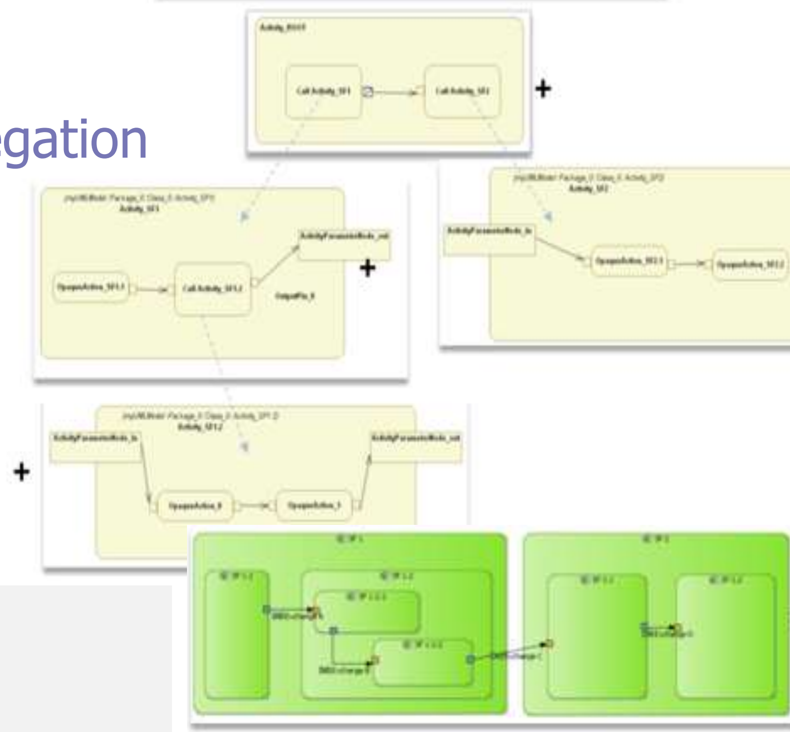


- ➔ Definition of in/out ports on functions, to express “direction for use” of the function
- ➔ Function/Ports definition is shared among all uses & diagrams
- ➔ Functional exchanges are also shared

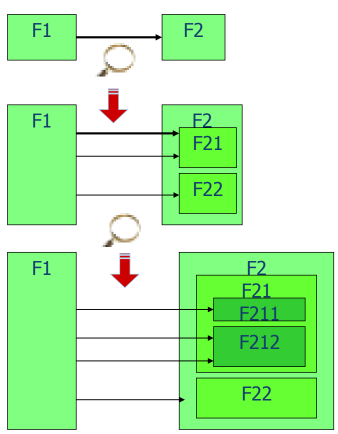
What Kind of Functional Analysis?

SysML blocks concept -like?

- ☹ Huge work to manage & update delegation of ports
- ☹ No direct link between feaf functions
- ☹ Not adapted to bottom-up approaches and model evolution



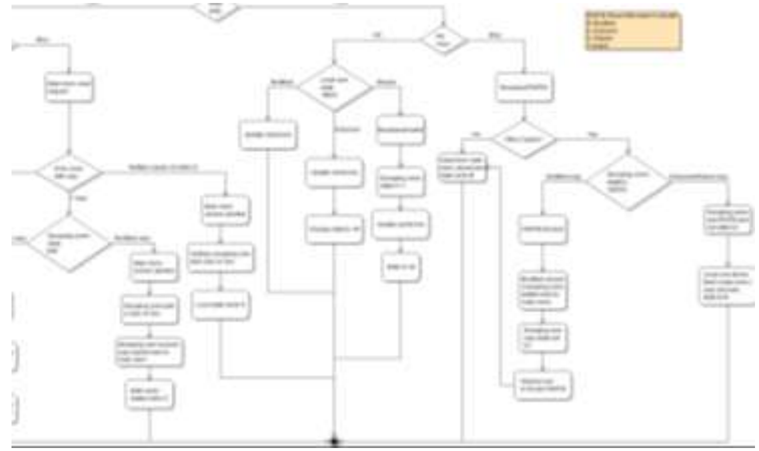
- ➔ Any function can be linked to any other
- ➔ Functional exchanges of the parent are just moved (drag & drop) towards the relevant child function in charge of managing the exchange
- ➔ Automated graphical synthesis at parent level

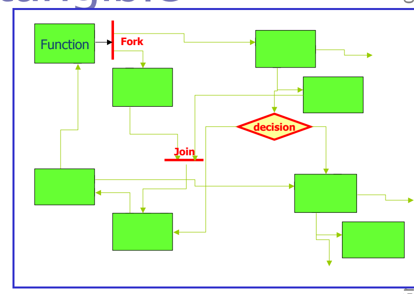


Data Flows or Activity Diagrams?

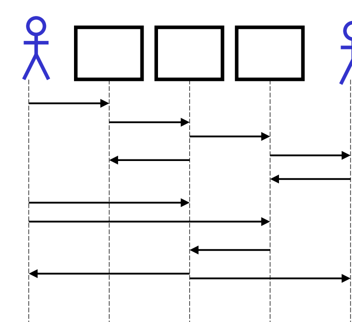
Activity diagrams?

- ☹ Mix data flow and sequence flow
- ☹ Same limits as IDEF0
- ☹ Poorly adapted to Architecture Definition (no control flow in interfaces!)
- ☹ Control flow depends on context, while dataflow is intangible





- ➔ Restriction to "Dataflow" concept and diagrams:
- ➔ Dependencies between functions, as expressed by (oriented) functional exchanges linking their ports,
- ➔ Nature of data, information, signals, and flows… exchanged between functions specified on exchanges.
- ➔ No pure sequence flow if no data is exchanged
- ➔ Scenarios (sequence diagrams) can express context-dependent ordering or precedence constraints



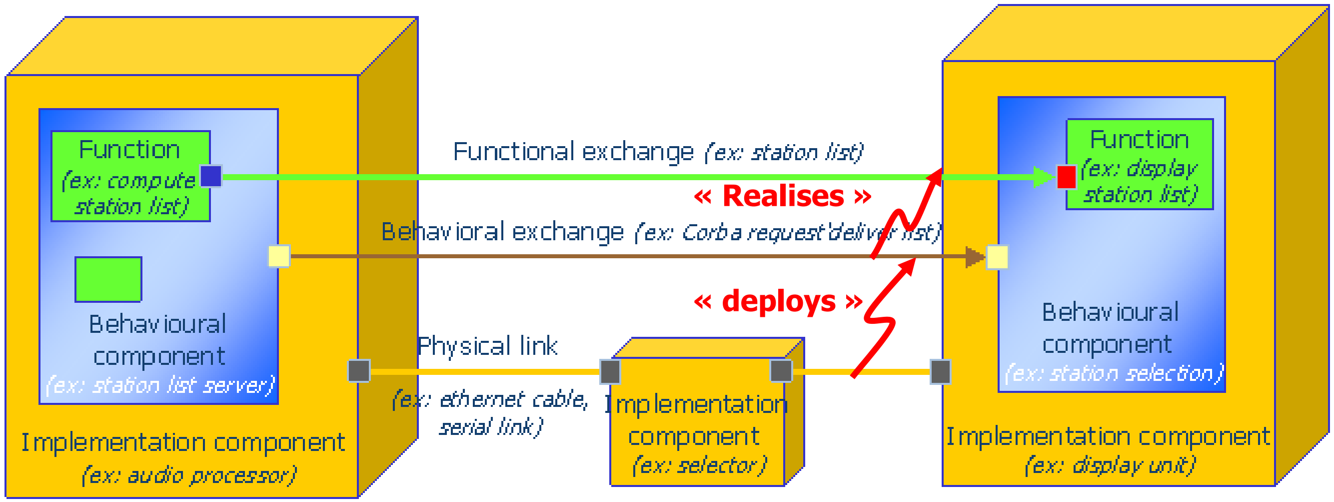
ARCADIA Capella

ARCADIA Concepts

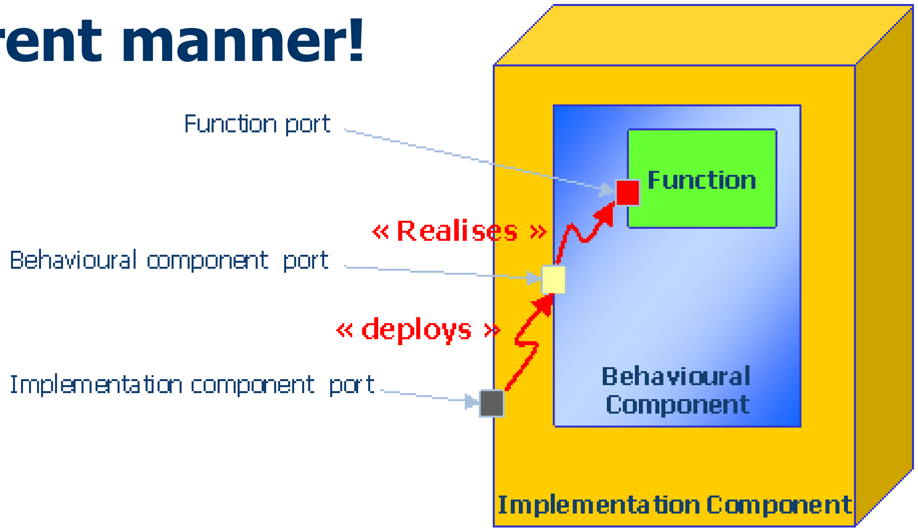
Focus on consistency and impact analysis, interface definition and justification

ARCADIA Capella

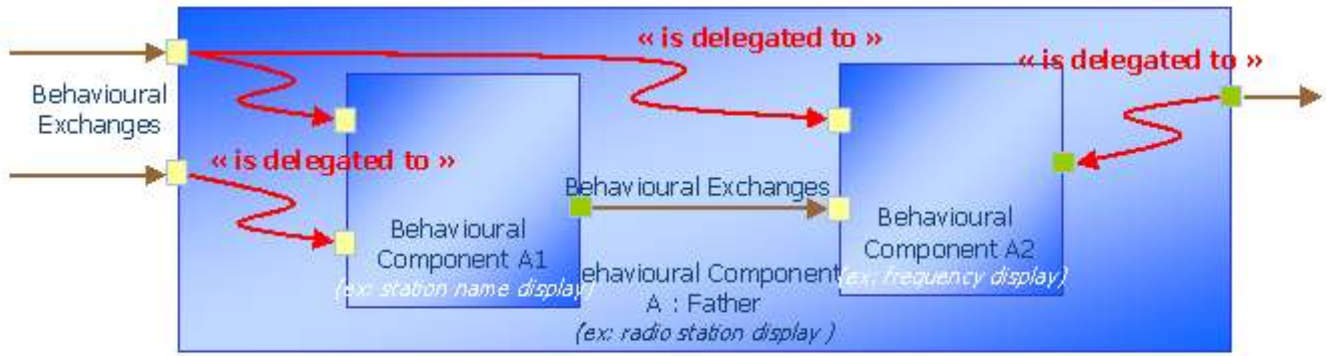
Connect elements

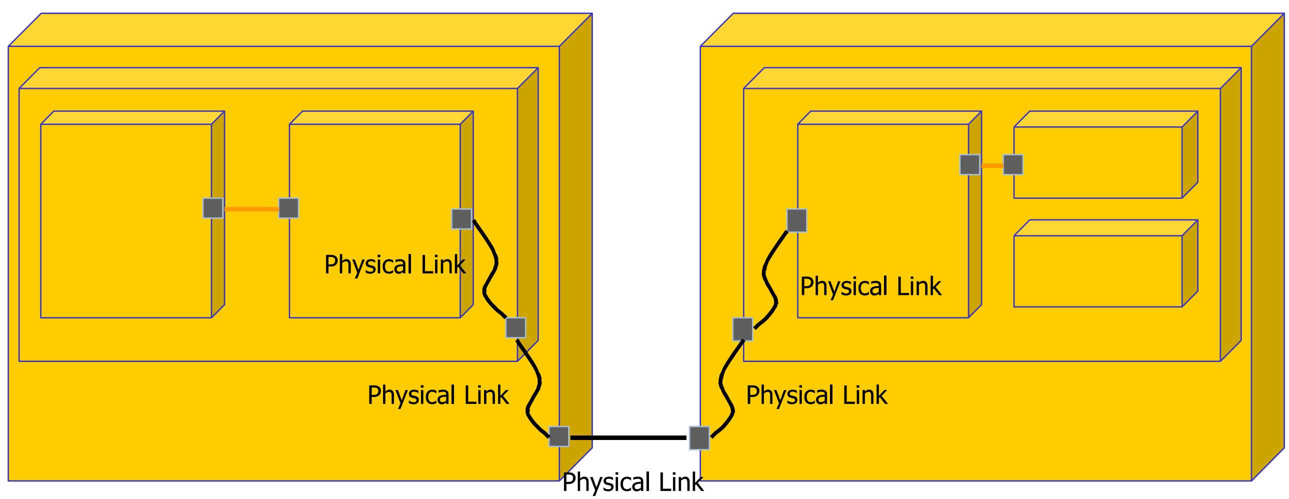


In a coherent manner!

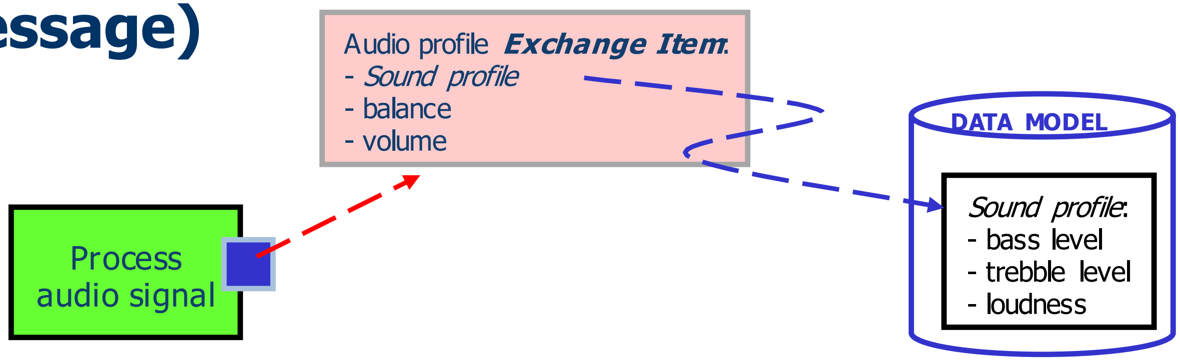


Routing data inside Components

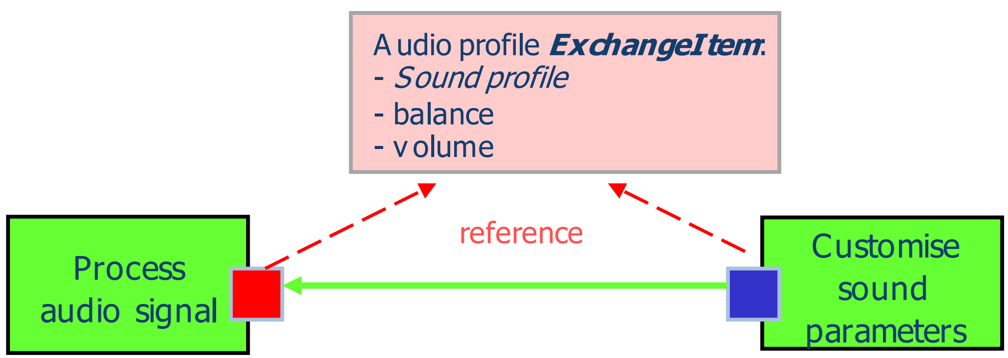




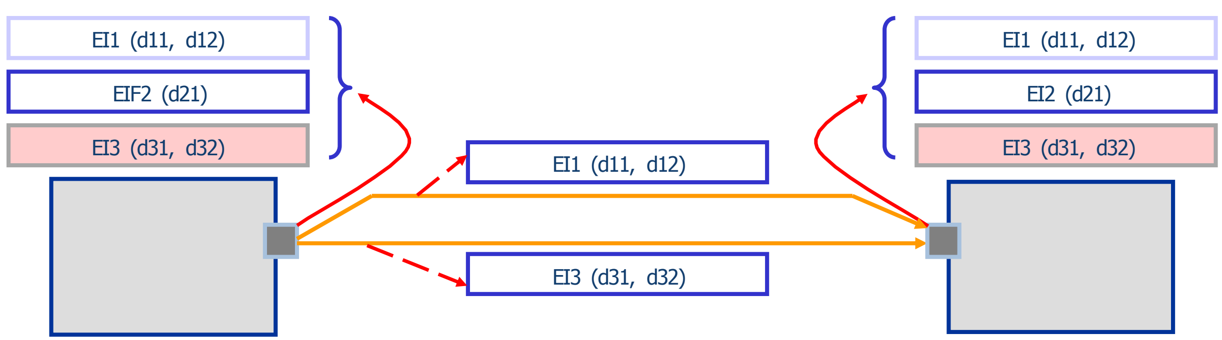
ExchangeItems group data to be used together (e.g. message)



Possibly for several similar uses

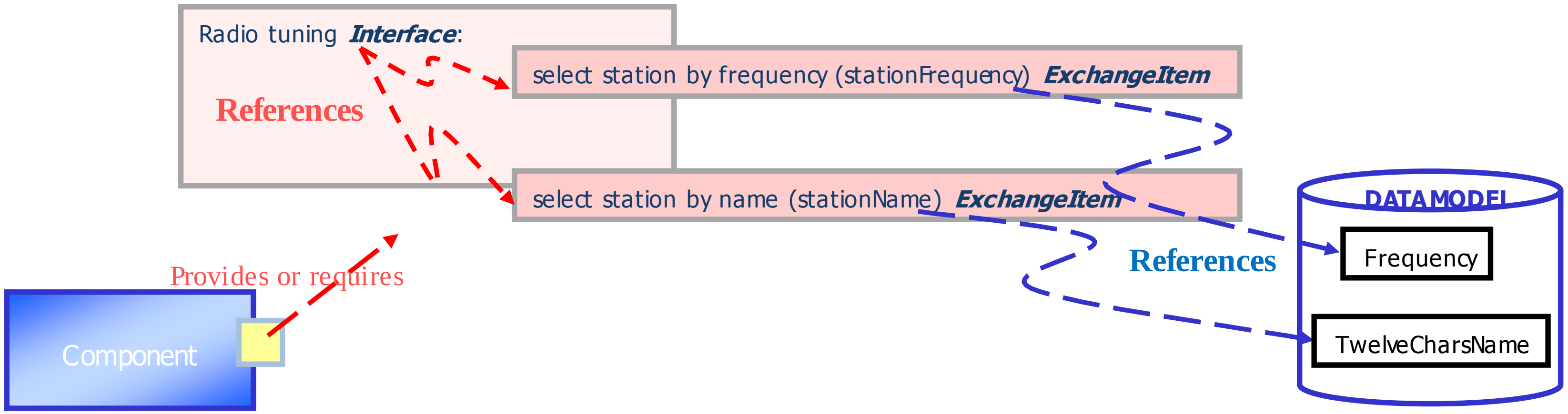


Coherency required!

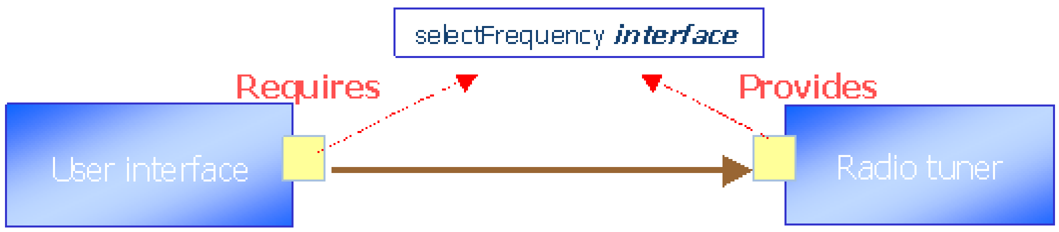


Capella

Same for Components, adding Interfaces in order to group exchangeItems



Sharing Interfaces



Coherency required!

ARCADIA Concepts

Early Validation: Multi-viewpoint approach for collaborative engineering and non-functional analysis

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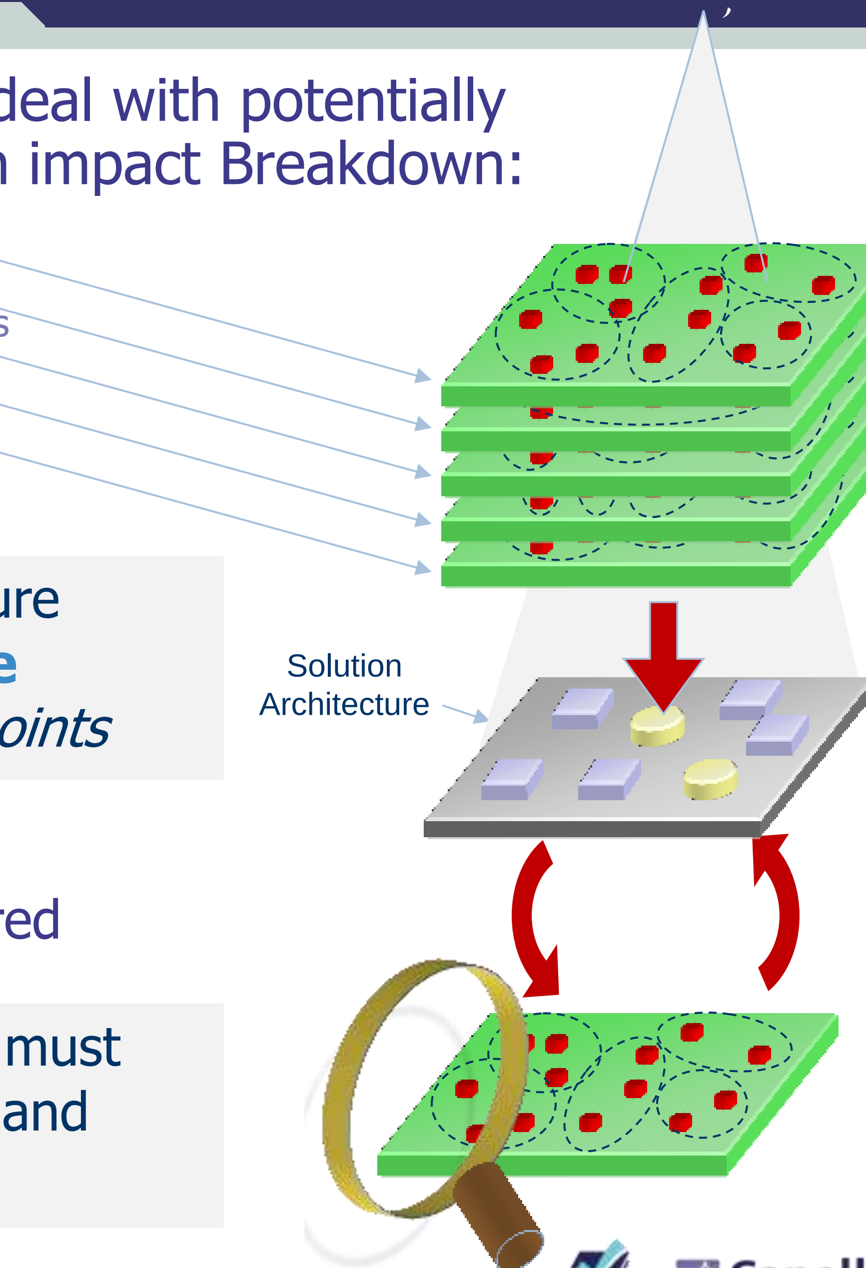
Architecture Building & Design: the Art of Compromise

The Product Architecture must deal with potentially contradictory Constraints, which impact Breakdown:

- Safety, Dependability / Fault Tolerance, Certification…
- Performances (reaction time & critical paths, processing capacities…)
- Maintainability, Reliability
- Mapping on [existing] hardware, middleware, reference Architecture…
- Functional grouping Consistency
- Weight, thermal dissipation, power consumption
- Cost, time schedule, skills
- Complexity of internal interfaces
- Human Factors
- Dependency in System Integration
- Security
- Ease of sub-contracting
- Reuse, existing Legacy, Product Line Policy
- Modularity, Ability to evolve
- Available technologies, COTS…

- Safety
- Performances
- Complexity of internal interfaces
- Ease of System Integration
- Cost, sub-contracting
- …



➔ Building an appropriate Architecture means finding the **most acceptable Compromise** between these *Viewpoints*

Then a detailed design & check according to each viewpoint is required

➔ Fine-grain Analysis per viewpoint must
- **start from architecture model**, and
- update/validate first hypotheses

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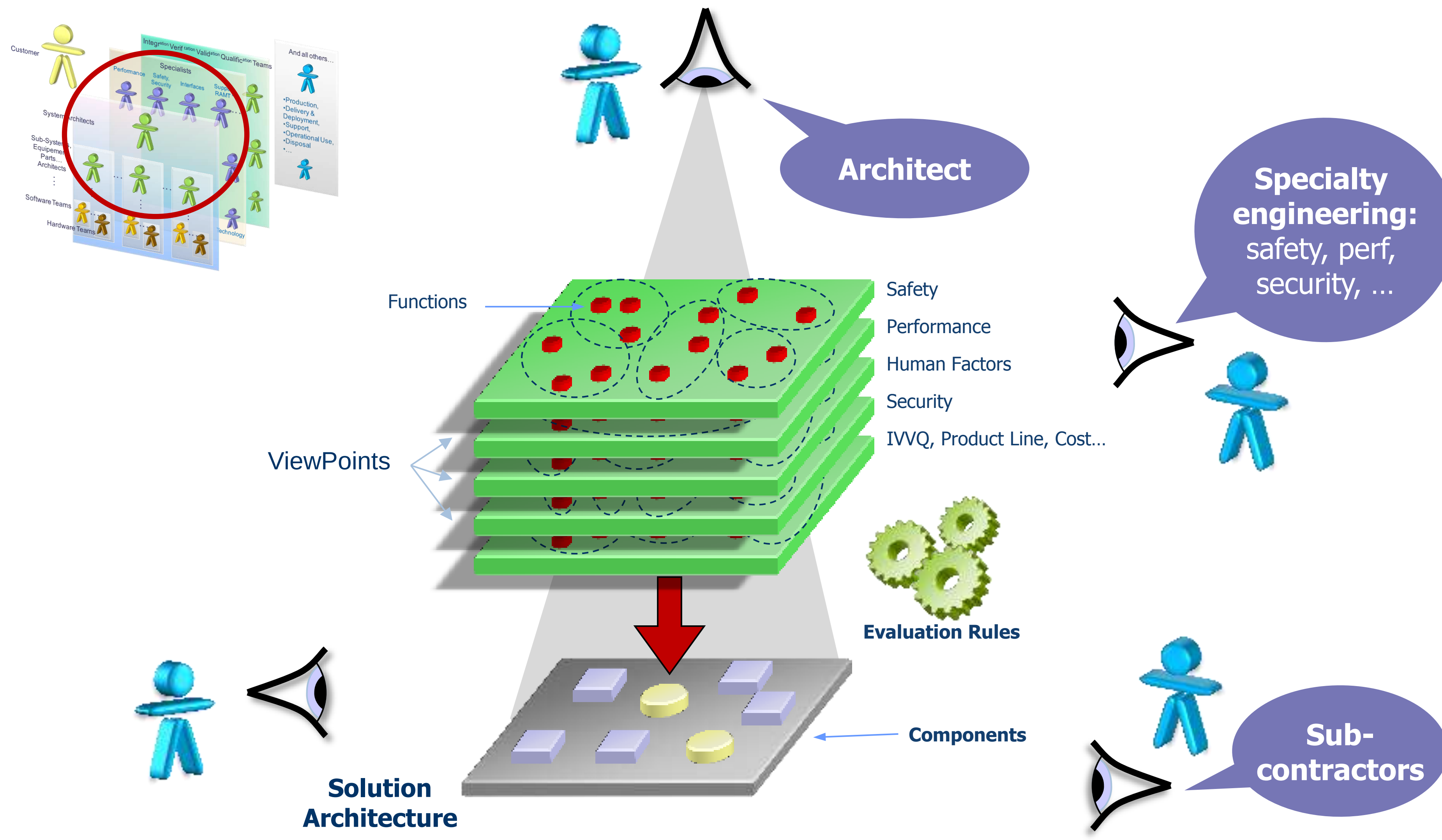
Early Validation: Specialities Know-how Confronted to Architecture



Multi-viewpoint trade-off analysis (see ISO 42010 standard)

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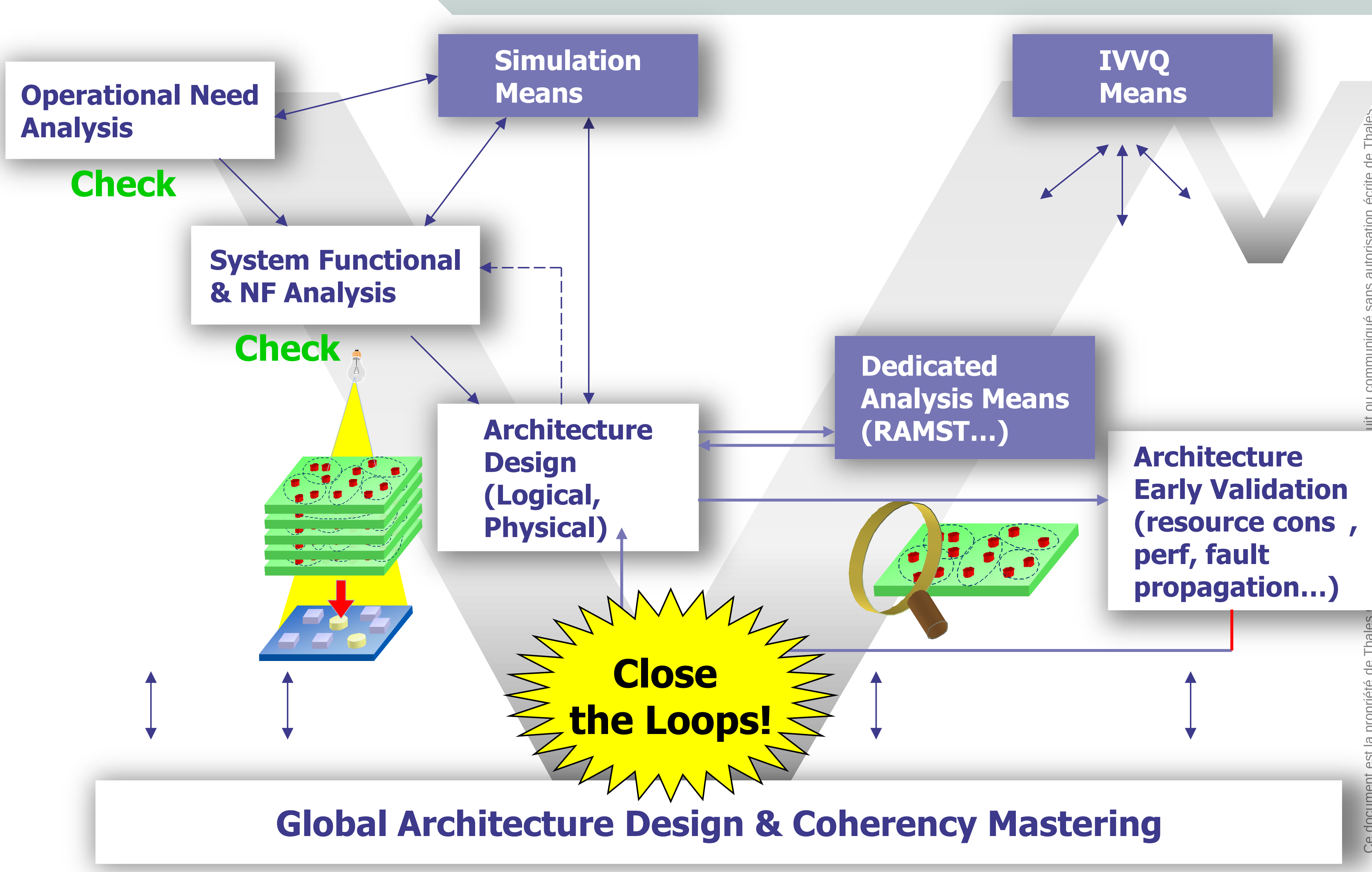
Architecture Definition Lifecycle Process



Method Adaptation to Each Domain: Know-how Capture

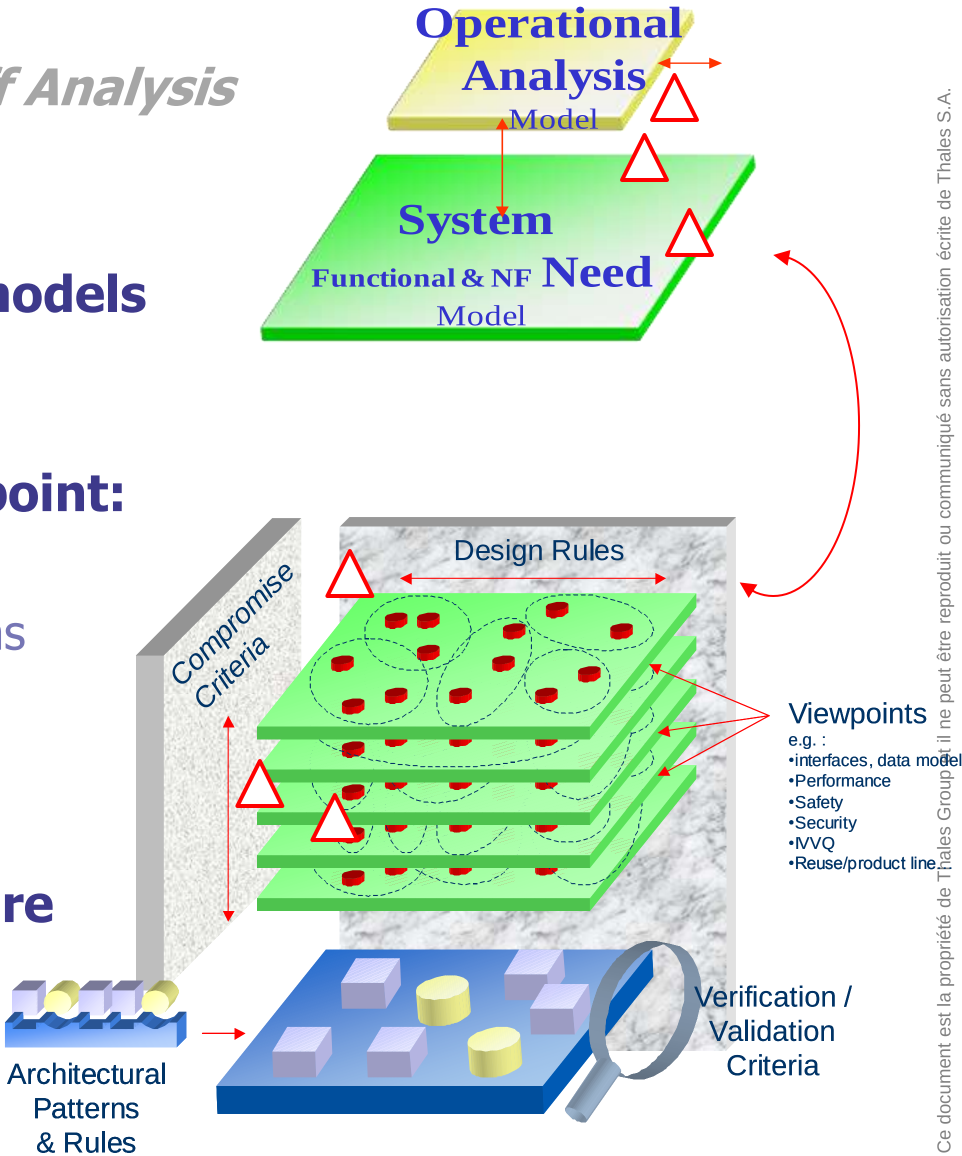
Support of multi-viewpoint Trade-off Analysis

- **Express N-F constraints & Need inside operational/functional need models**

- **Capture domain know-how on common architecture for each Viewpoint:**
  - Dedicated concepts (model extensions)
  - Architecture checking rules & algorithms
  - Dedicated diagrams and graphical annotations

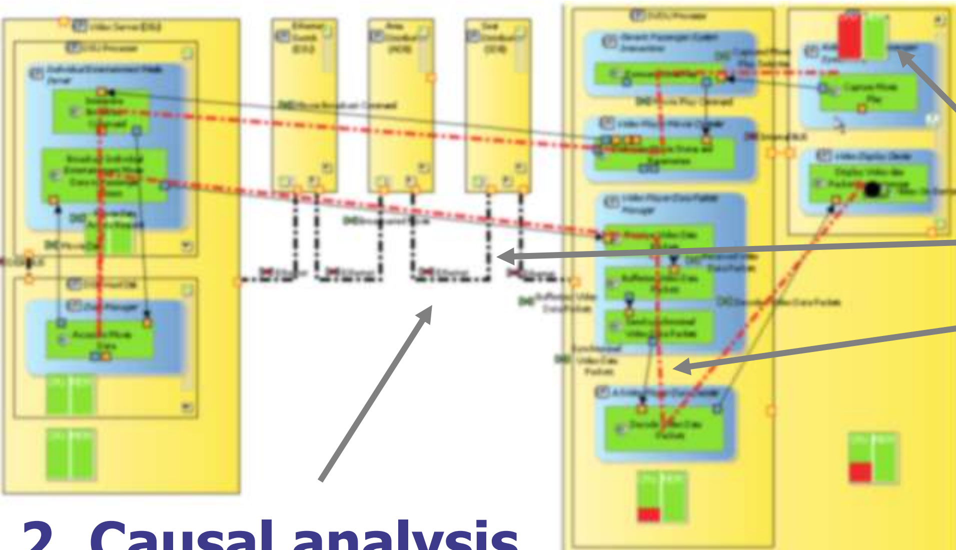
- **Analyse each candidate architecture against all viewpoints, locate defects and correct**

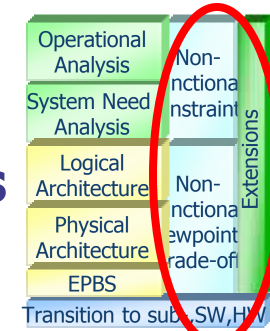
- **Quickly Iterate**



Supported in Capella

Performance Non-Functional Viewpoint





1. Automatic analysis

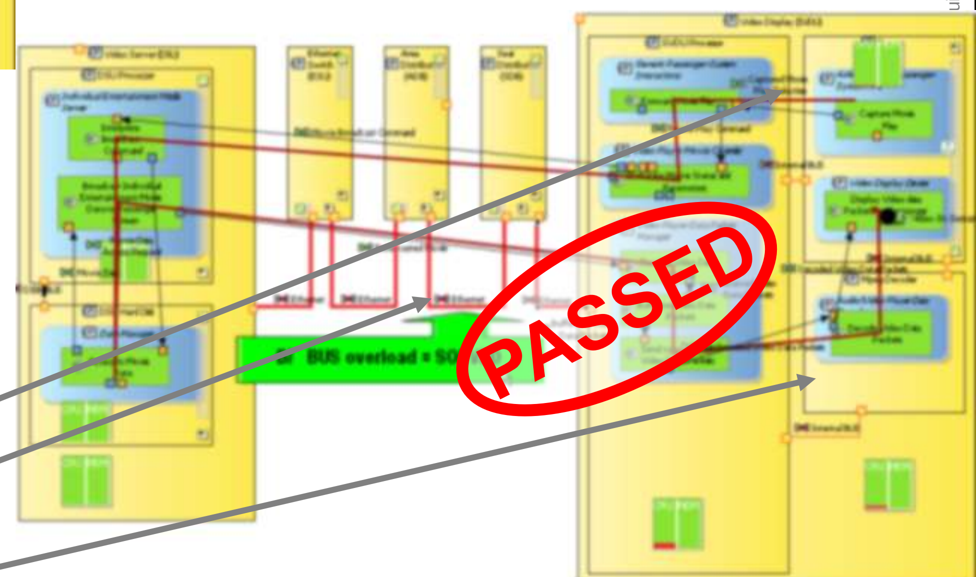
- CPU overloaded
- Bus overloaded
- Latency too high

2. Causal analysis

- **Tool locates problems**
- Quantitative analysis

3. Architecture improvement

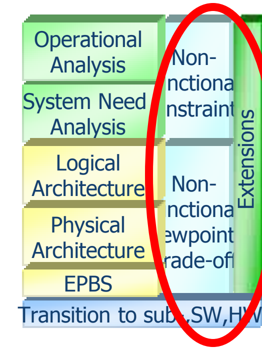
- Lighter protocols
- Higher bandwidth
- Hardware processing

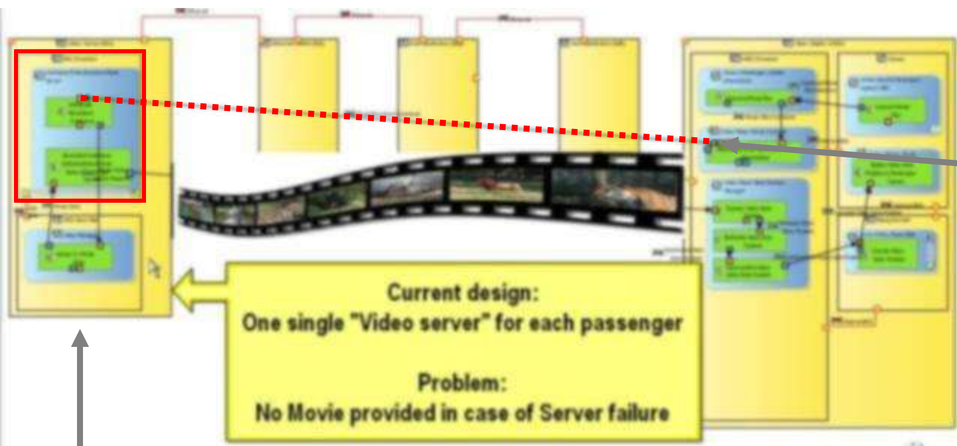


Require additional Capella viewpoints

Capella

Safety Non-Functional Viewpoint





1° Automatic analysis:

- Rule: "*No single source for major failure condition*"
- Not met for video

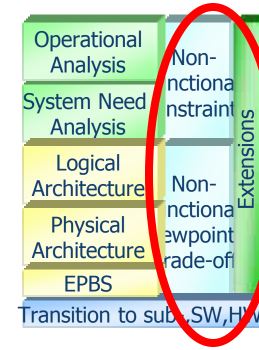
2. Causal analysis

- **Tool locates problems**
- Failure propagation algorithm

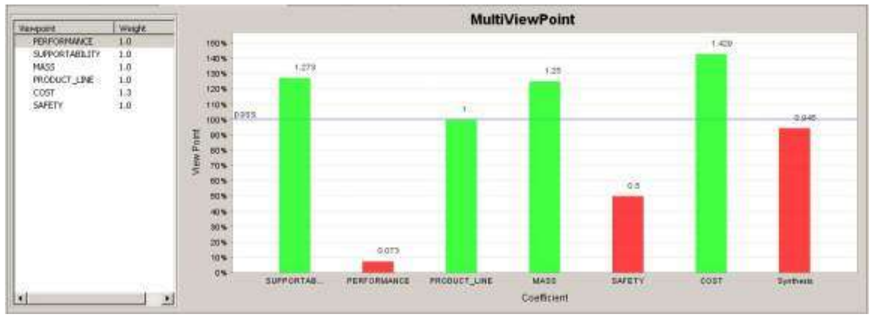
3. Architecture improvement:

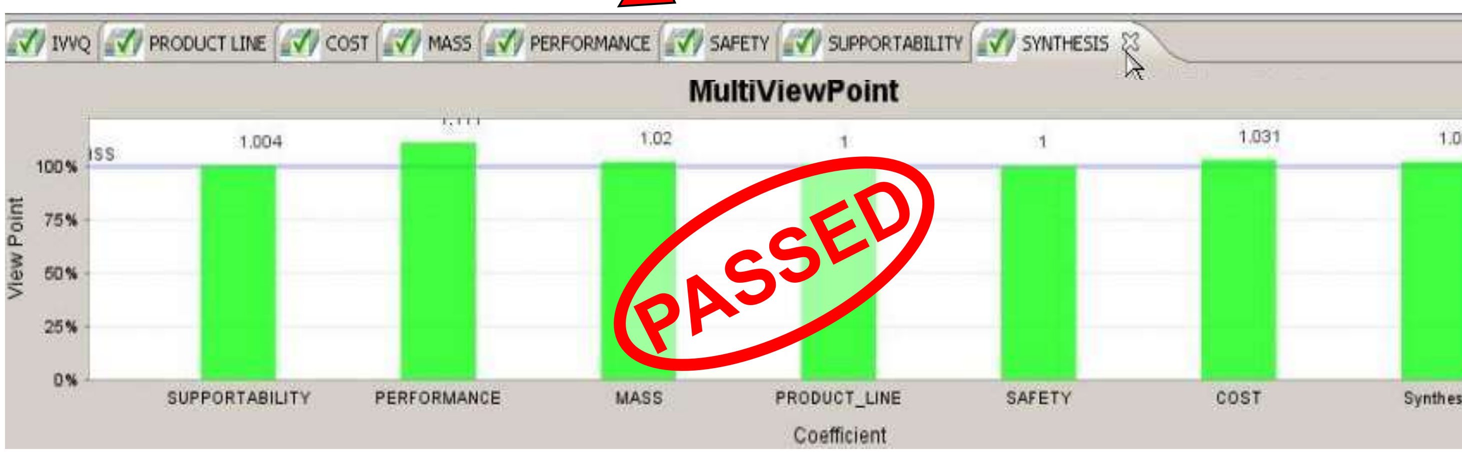
-Second redundant server

Require additional Capella viewpoints



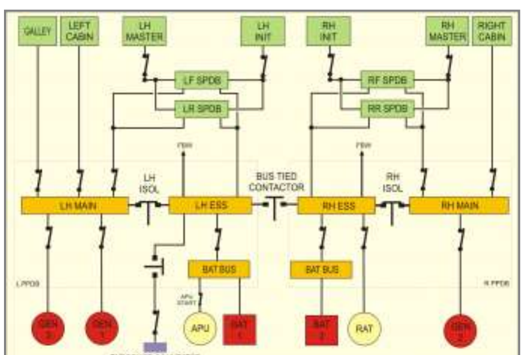
Confrontation rules for multi-viewpoints trade-off





Histogram view will be available in Capella in 2015 (see Kitalpha)

Other example of Modelling & Validation: On-board Electrical Power System



Energy & Thermal system Of a commercial Aircraft

Three Interleaved, Multi-Physics Models

Power Model

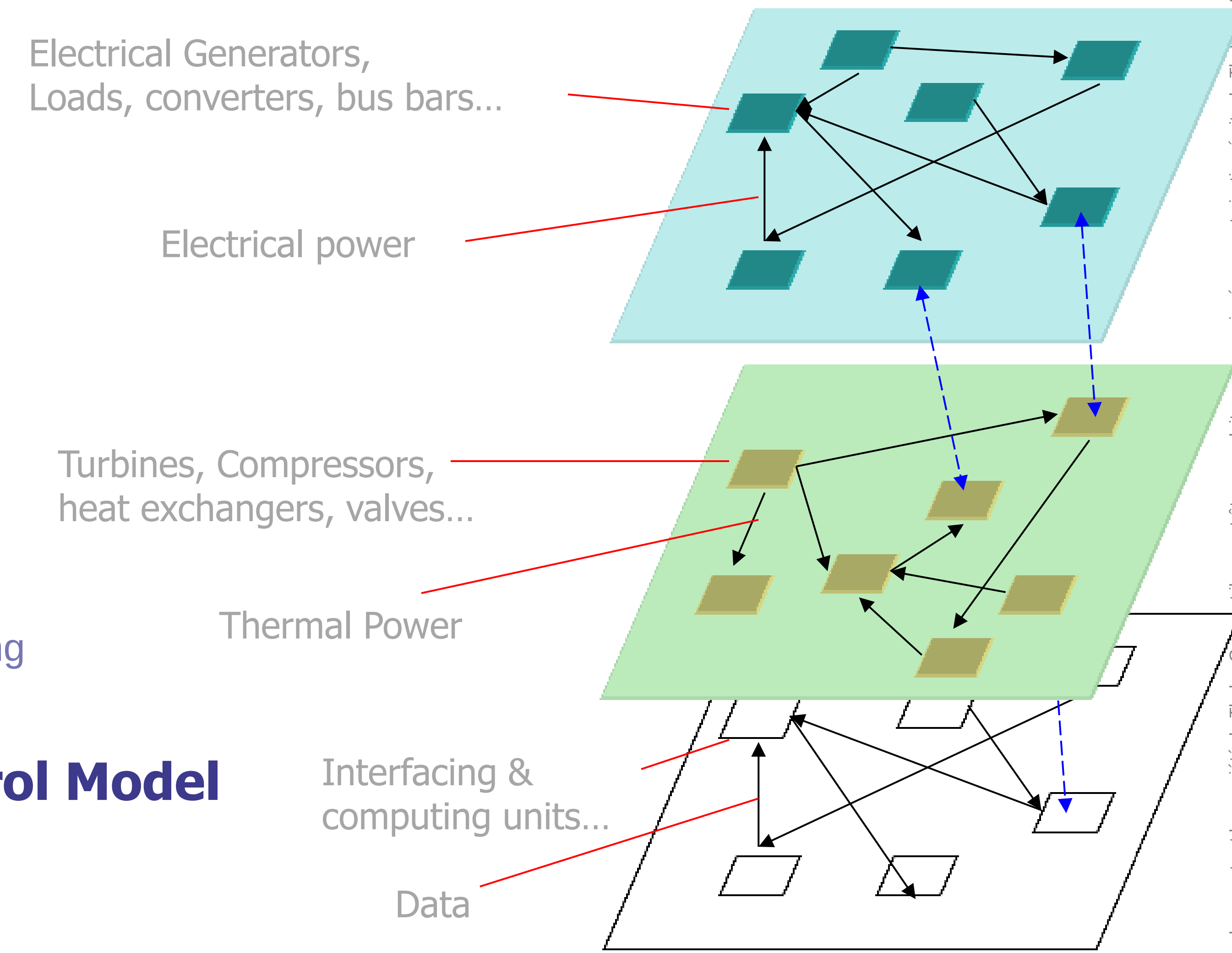
-Generation
-Distribution

Thermal Model

-Conditioning
-Pressurisation
-Equipments Cooling

Command & Control Model

(coming soon)



Power Systems Example: Dedicated Viewpoints

Power & Thermal performance

depending on flight phase consumption, incl. Overloaded components detection based on power computation, linked to thermal Model

Safety / Integrity

incl. Failure containment, redundancy rules & analysis, failure scenarios & propagation, monitoring efficiency, shielding…

Reliability & Availability

incl. Reliability computing, reconfiguration issues, flight delay…

Spatial (3D) arrangement

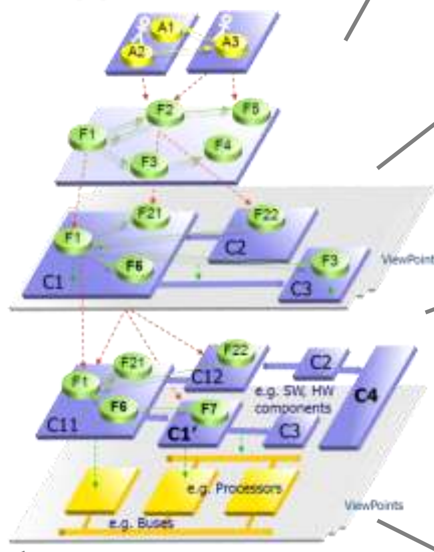
Early identification of spatial arrangement constraints impacting the architecture

And also: Mass, Cost, Reliability…

« Model Once, Use Many »: The Blue Line Vision

One model, many users…

…and many other uses…

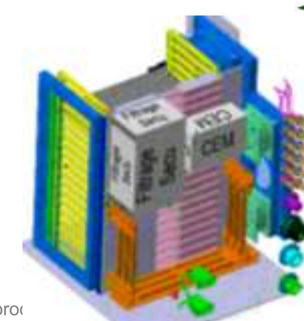


Engineering documents: SSS, IRS, SSDD, ICD, SRS, …

User & Maintenance Documents

Electronic Interface & data generation

Test bench specification



3D Computer Aided Design

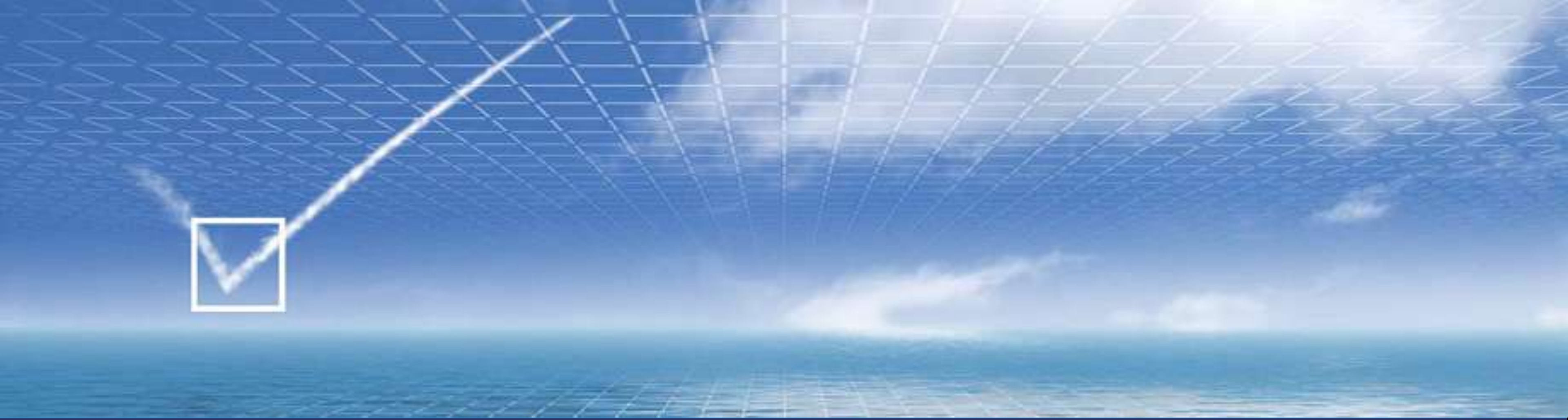
…and more

Metrics, Risk Management

Wiring, Development & Production Means…

ARCADIA

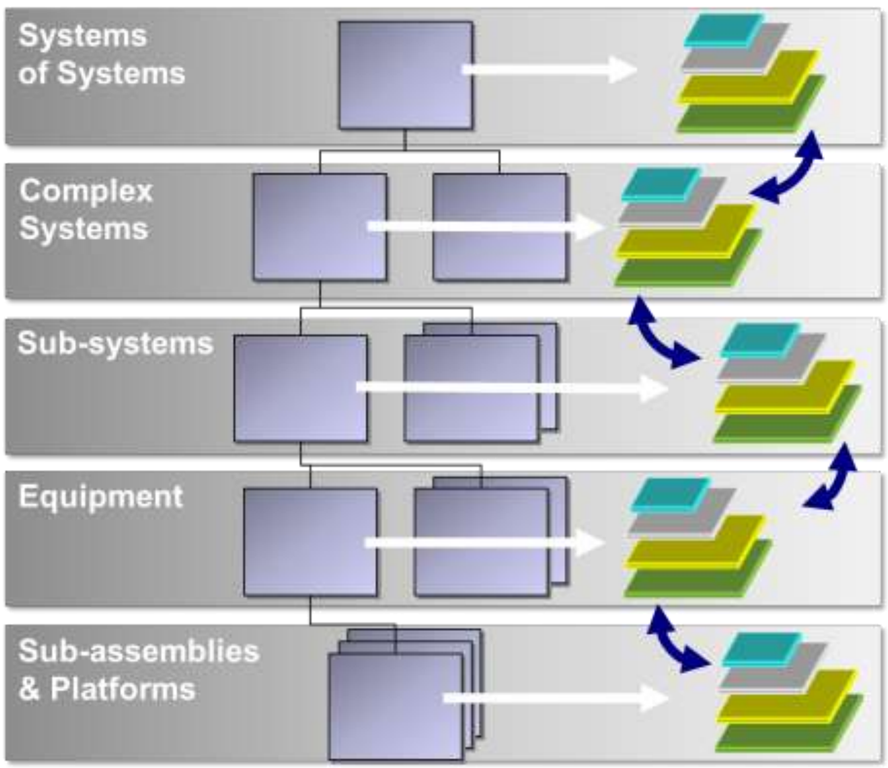
Capella



ARCADIA Methodological Approaches

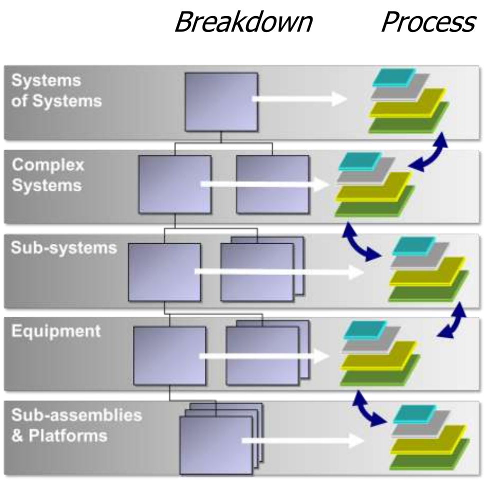
Transition, relationship to requirements, IV&V

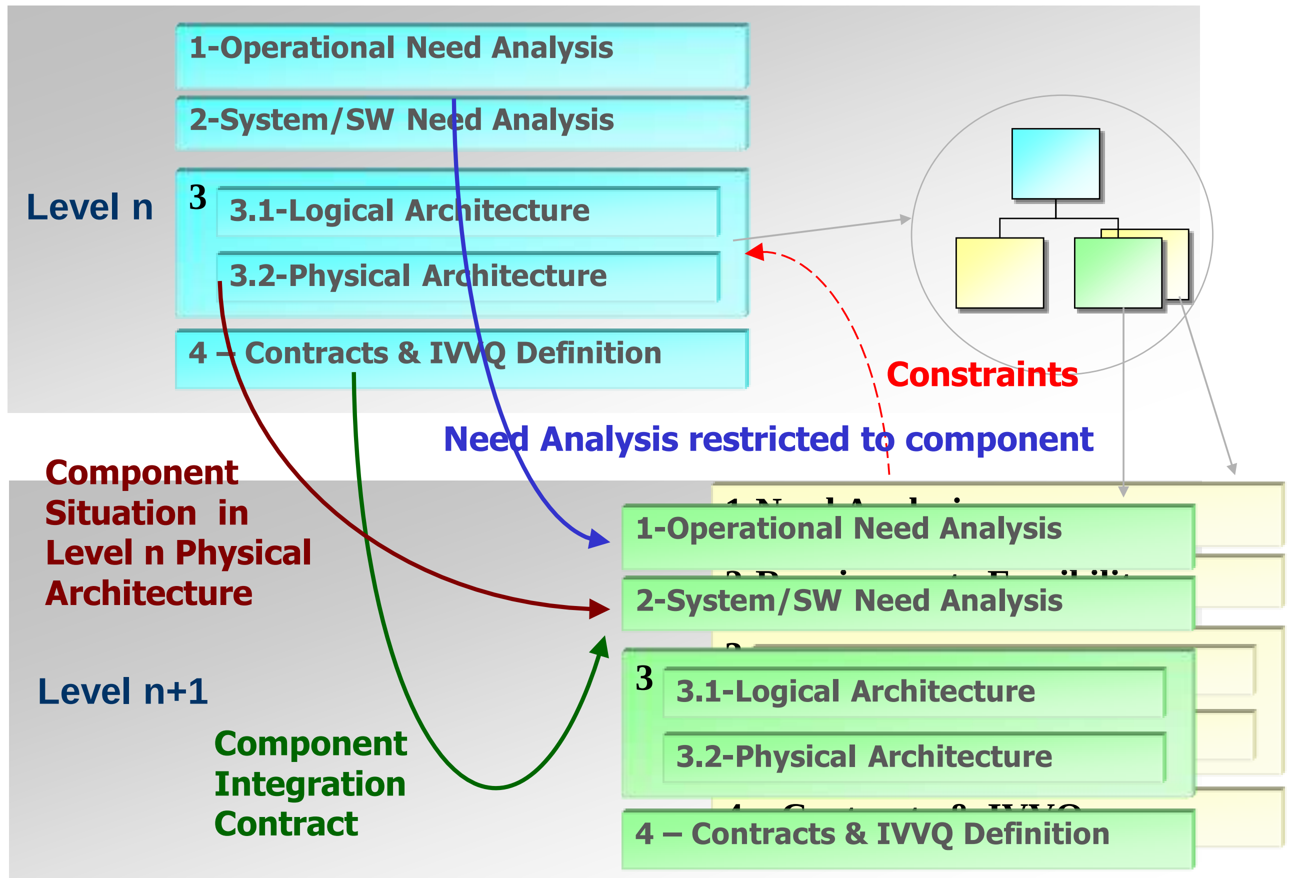
Support of Consistency Between Engineering Levels



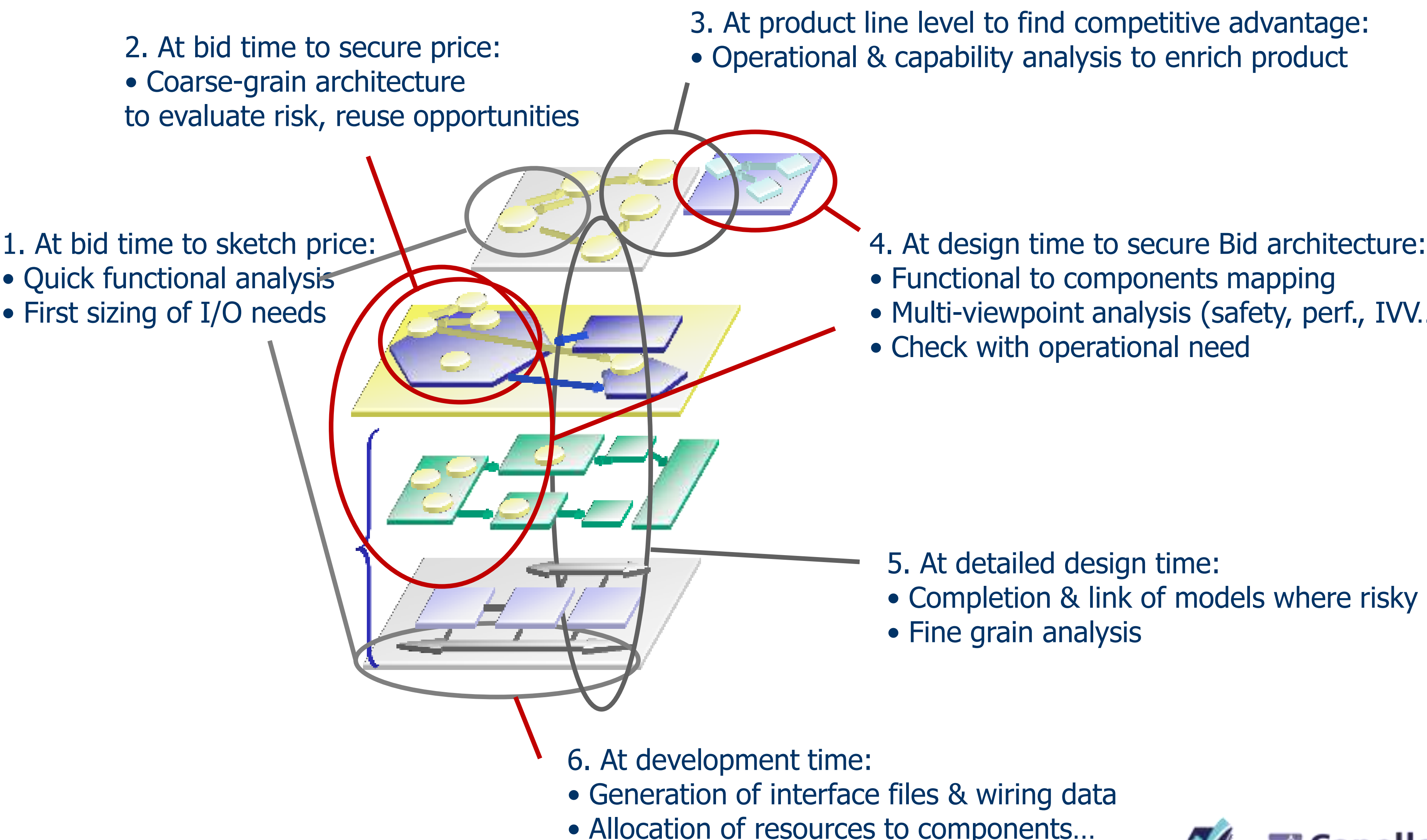
- **Automated Transition between Engineering Levels**
  - Iterative, conservative
  - Coherency control
- **Mastering complexity through multiple abstraction levels**

Recursive Application to Each Engineering Level





Example of progressive building



IV&V : A New Approach is Required for Engineering

- New model-based engineering approaches such as ARCADIA seek (among others) to overcome textual requirements limitations

- **The need is formalized in a shareable form, that can easily be analyzed and validated**
  - Operational and functional analysis
  - Traceability links with textual requirements

- **Textual requirements are complemented (and not replaced)** and validated by models and their use

- **The solution is formalized, traced and justified** (partially validated) by the model architecture

- Previous traceability links are now based on a unifying model and an explicit and verifiable process that secures engineering

IV&V : integration, verification, validation

Scoping and Articulation with Textual Requirements

For Customers who require it, textual requirements are still the main vector

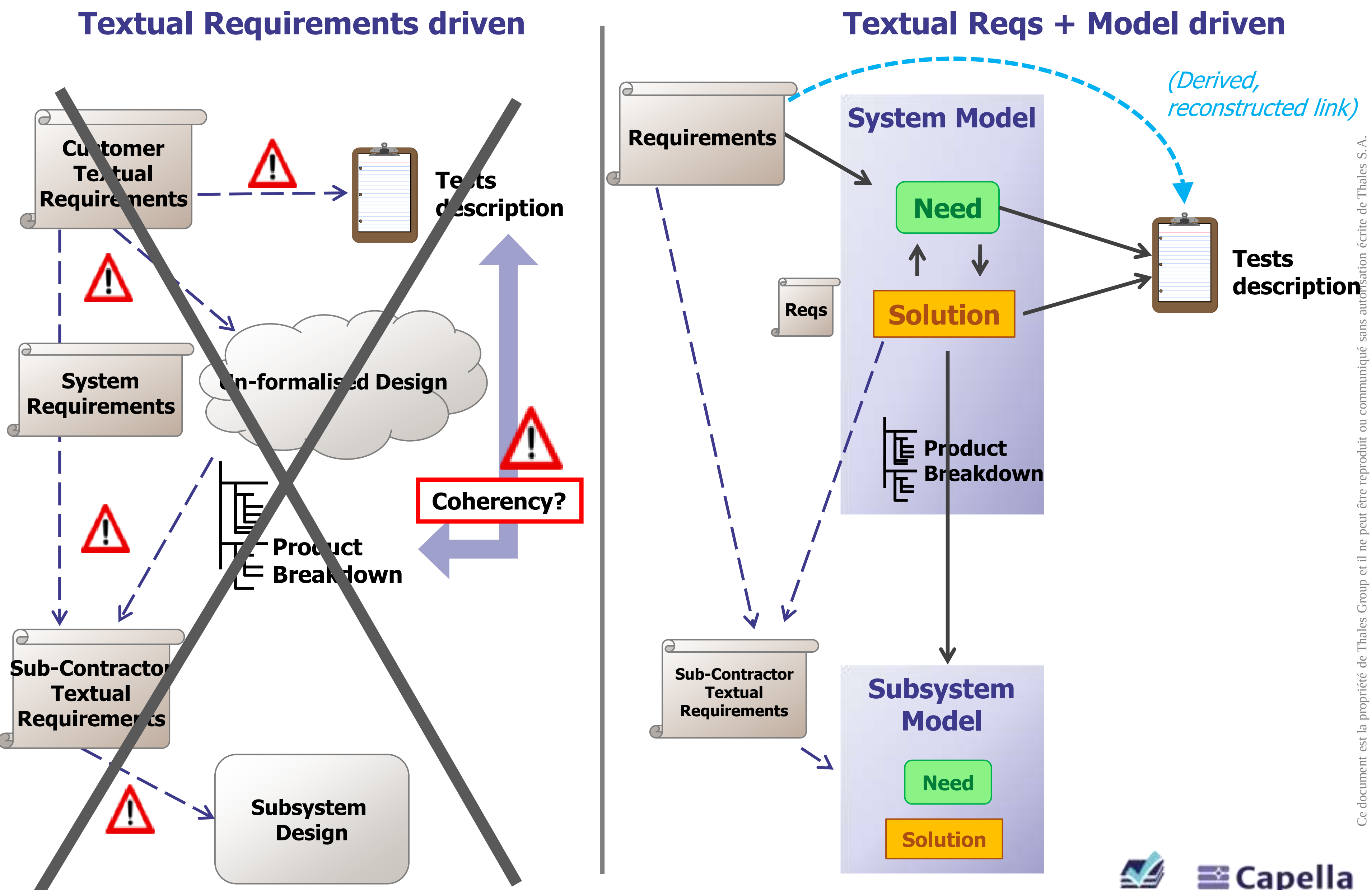
- **For the Customer, Functional description is an explanation and / or additional support deepening specifications**
- Traceability towards engineering artifacts (architecture, tests ...) is still ensured by User Requirements (UR)
- It is made internally through the model: requirements <-> model <-> artifacts
- **System Requirements (SR) add to the UR only those requirements that are strictly necessary to communicate and validate the need**
- Based on the model as a negotiation support

Scoping and Articulation with Textual Requirements

Internally, models carry most of the description of need and solution

- Anything that can be efficiently expressed in the model is formalized that way (“modeled requirements”)
  - In this case, it is unnecessary to create or refine textual requirements (would be redundant)
  - Internal requirements (textual) are added where necessary:
    - Either to express a constraint or an expectation, more precisely than the model,
    - Or if it is difficult to represent and capture a specific need in the model
- The **customer requirements (UR) remain traced in the model** and towards engineering artifacts, for justification purposes
- Engineering, subcontracting and IVVQ are driven by the model
  - (To be adjusted according to the maturity of subcontractors)
- A posteriori check of coverage / satisfaction of these requirements is done

Comparing Approaches for Requirement Engineering

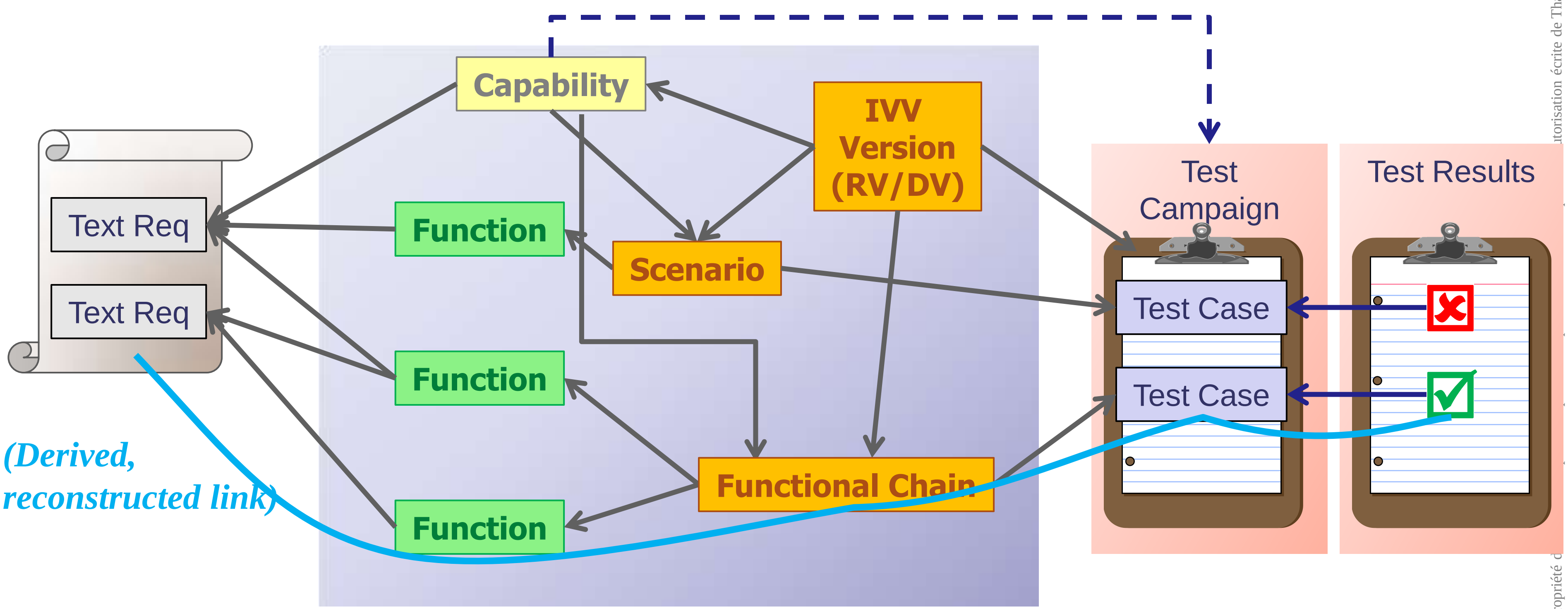


Test, Integration, Verification, Validation Principles

- Test campaigns are constructed from model scenarios and functional chains
  - Refinement (detailed scenarios, not nominal ...), complements, details (ranges, expected results ...)
  - Traceability links
    - Between test campaigns and delivery versions
    - Between tests and scenarios / functional chains
- Validation of textual customer requirements is achieved by exploiting the indirect links
  - Tests - scenarios / CF - functions – requirements

Test, Integration, Verification, Validation Principles

Requirements | Model | IVV Management



Using ARCADIA Engineering Models to Drive IV&V

Define IVV Strategy

Master Development Ups and Downs

Control Maturity of Deliveries

Optimize IVVQ Globally
(incl. Enabling Systems / Test Means)

Focus on Functional Content and Architecture

ARCADIA

Operational Need, Functional Contents

System Components

Test Benches

Mission System
Radar
Receiver
Software/HW

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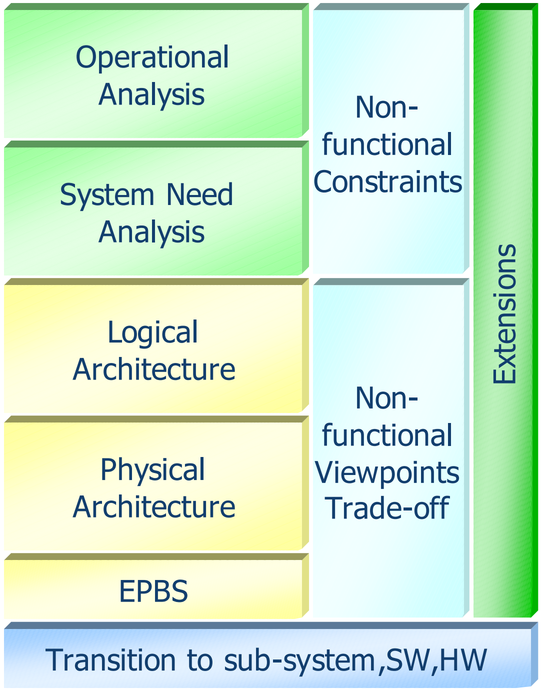
ARCADIA wrt Standards: xAF, SysML, AADL…

Yet another Formalism?

ARCADIA Scope & Coverage (1/2)

ARCADIA goes beyond Formalisms & Languages:

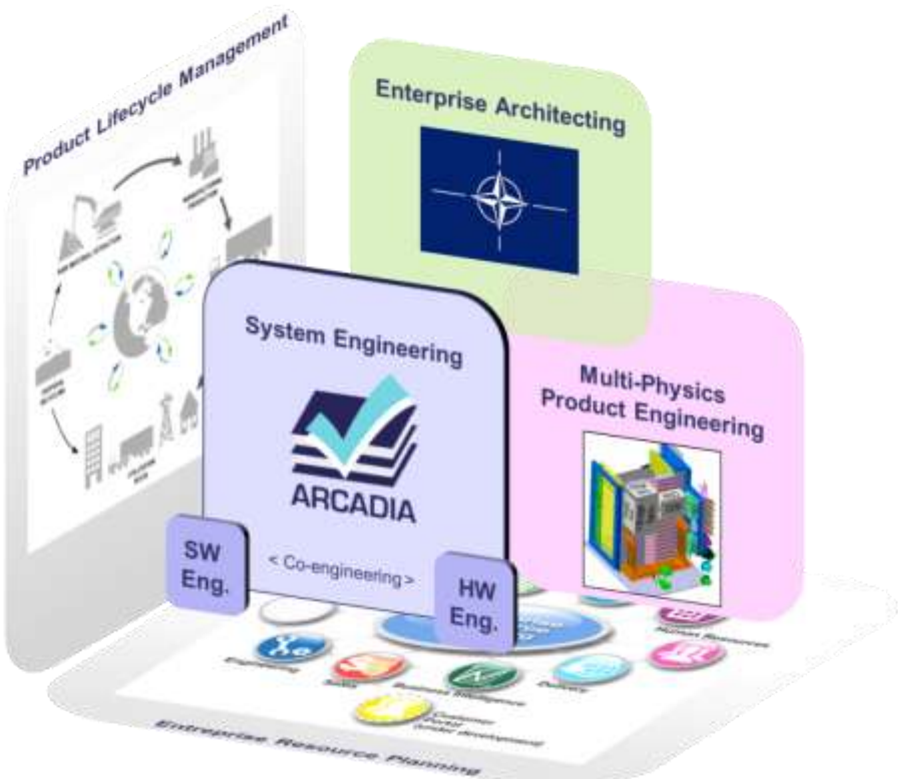
- Method defining full model design & conformance rules
  - How to define elements
  - How to link and relate them to each other
  - How to justify and check definition
- Operational Analysis & Capability integration
- Modelling Viewpoints
  for non-functional constraints support
  - Safety, Performance, HF, RAMST, Cost…



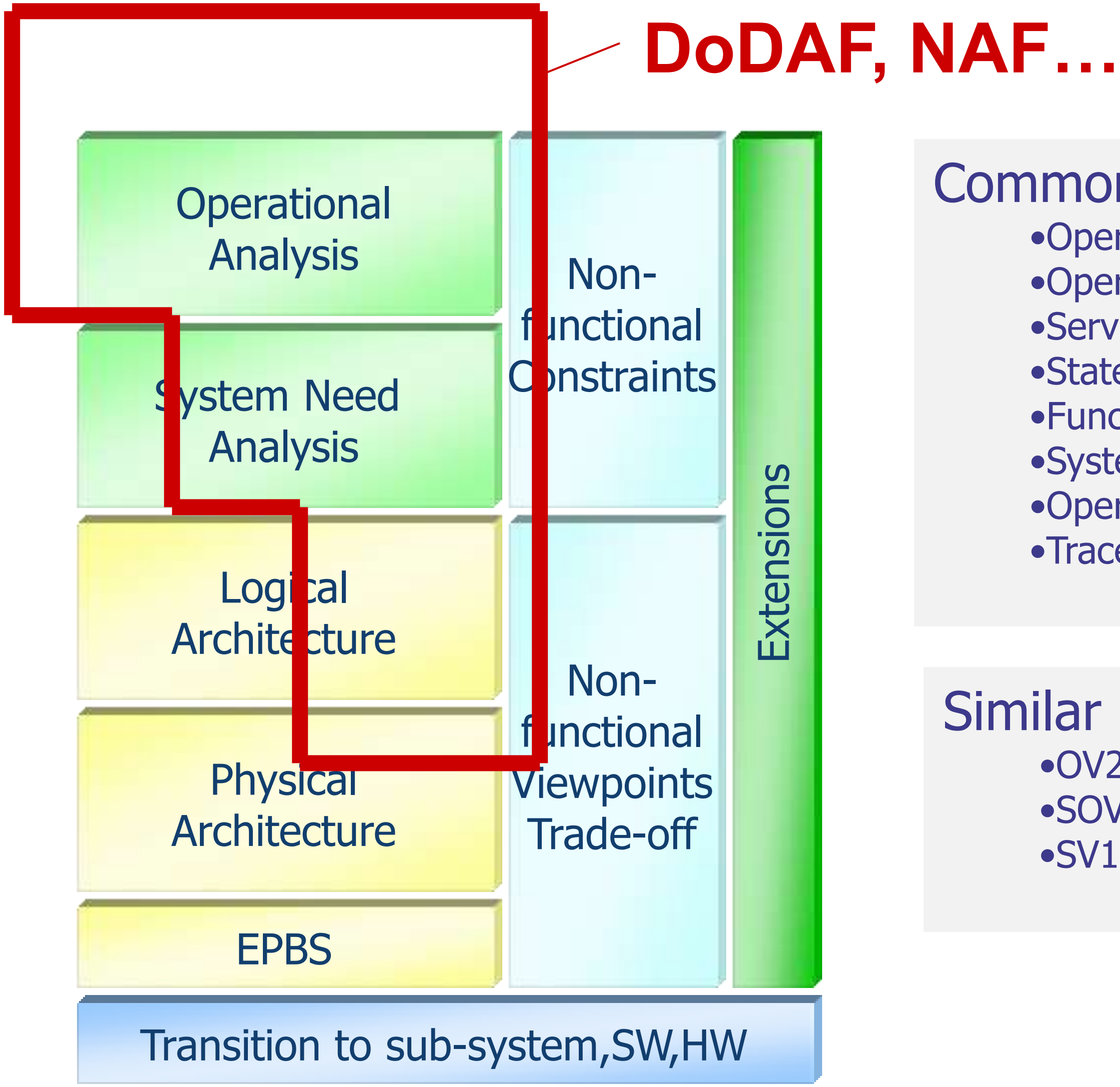
ARCADIA Scope & Coverage (2/2)

ARCADIA goes beyond Formalisms & Languages:

- Semantic architecture Validation through Engineering Rules formalisation
- Multi-viewpoints analysis coupled with fine-grained tuning
- Extensible: viewpoints, model, diagrams & rules



ARCADIA Formalism Vs DoDAF, NAF…



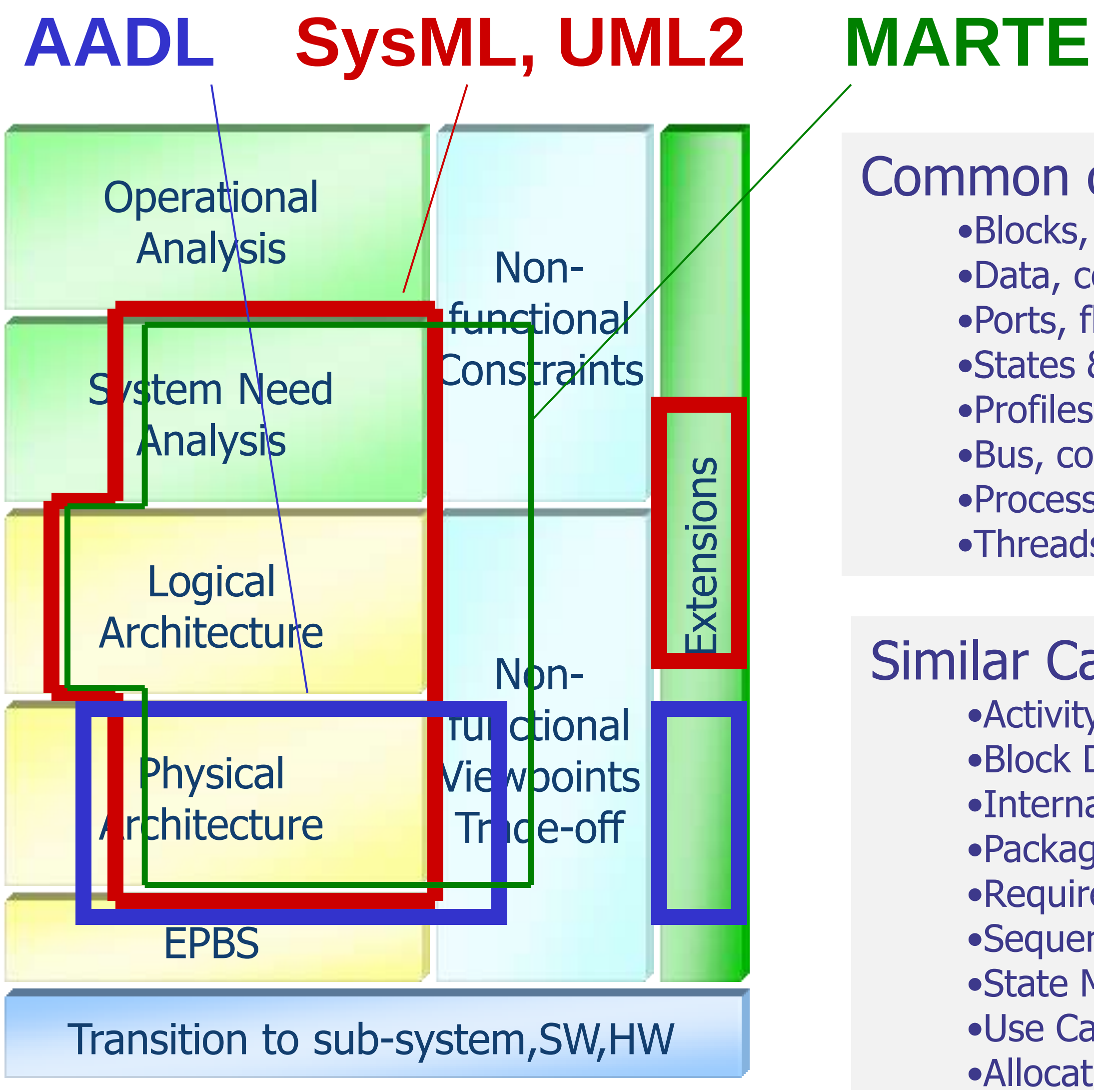
Common or Similar Concepts:

- Operational Entities, Actors, Roles
- Operational Activities, Processes
- Services (extension)
- States & modes
- Functions, dataflows
- System Nodes, equipment (generalised)
- Operational & system data…
- Traceability between operational & system

Similar Capella Diagrams:

- OV2, OV4, OV5, OV6, OV7;
- SOV;
- SV1, SV2, SV4, SV5, SV10…

ARCADIA Formalism Vs UML2, SysML, AADL…



Common or Similar Concepts:

- Blocks, parts, (sub)components
- Data, constraint properties
- Ports, flows
- States & modes
- Profiles & libraries…
- Bus, connection
- Processors, Memory… (extension)
- Threads, processes… (extension)

} AADL

Similar Capella Diagrams:

- Activity diagram,
- Block Definition diagram,
- Internal Block diagram ,
- Package diagram,
- Requirement diagram,
- Sequence diagram ,
- State Machine diagram ,
- Use Case diagram ,
- Allocation tables…

ARCADIA Capella

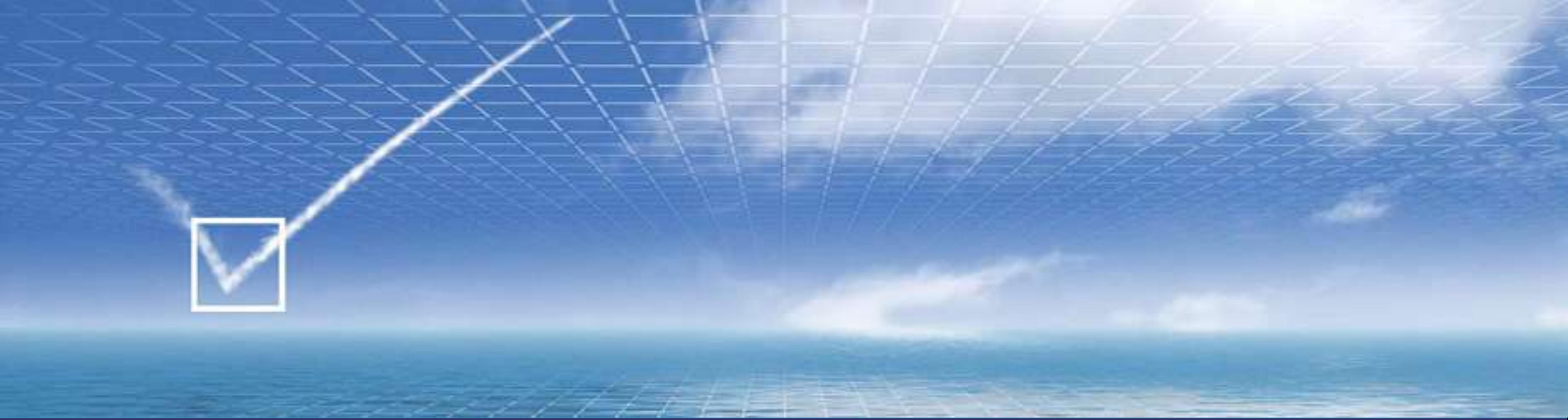
ARCADIA Vs Architecture Languages

ARCADIA concepts are directly compatible with architecture languages such as

- DODAF/NAF Architecture Frameworks,
- UML2 & SysML,
- AADL, …

These formalisms can interoperate with ARCADIA, it is just a matter of import/export tooling:

- Export tooling can (will) be developed,
- Selective Import can (will) be developed (e.g. functional analysis, components…)
- Global Import could be possible under method conformance conditions

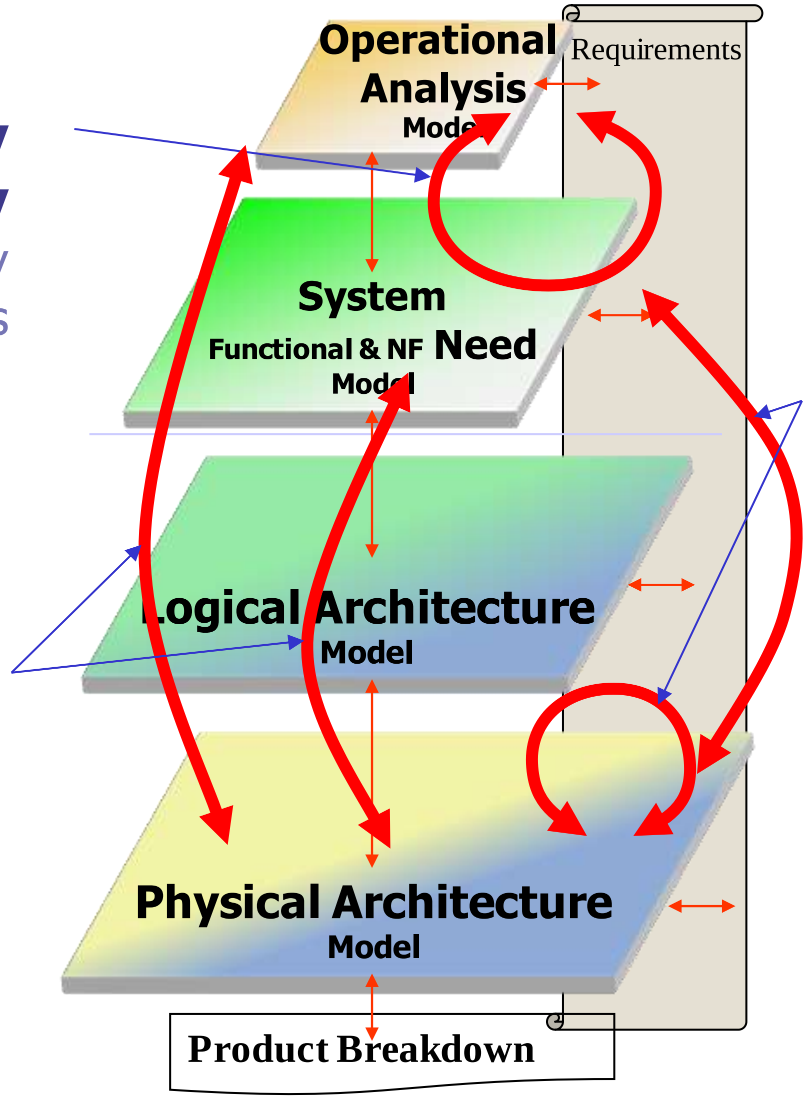


Benefits of ARCADIA

A quick summary of features and capabilities

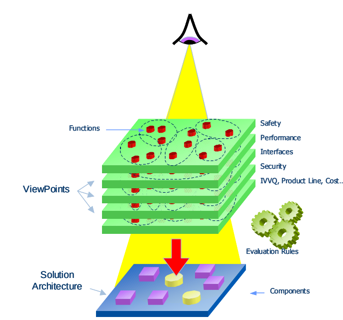
Early Validation: How to Validate Architecture vs Need

Need consistency & coherency
Traceability links



Impact analysis: Architecture vs operational & functional need confrontation
Traceability & implementation links

Architecture Vs non-functional need confrontation
Viewpoint analysis traceability & implementation links



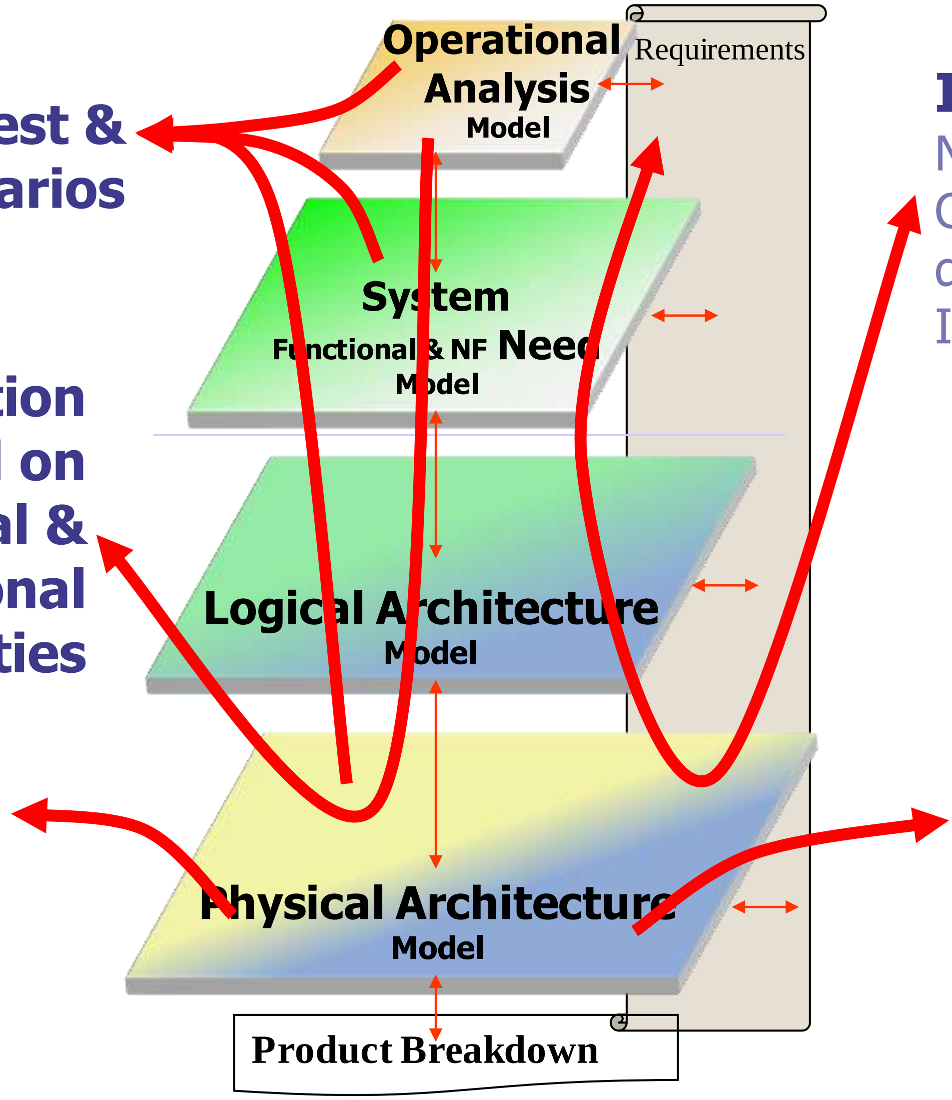
ARCADIA
Capella

Need & Architecture Driving Integration Verification Validation

Definition of test & IV&V Scenarios

Deliveries definition based on operational & functional capabilities

Definition of test benches & simulation needs



Impact analysis

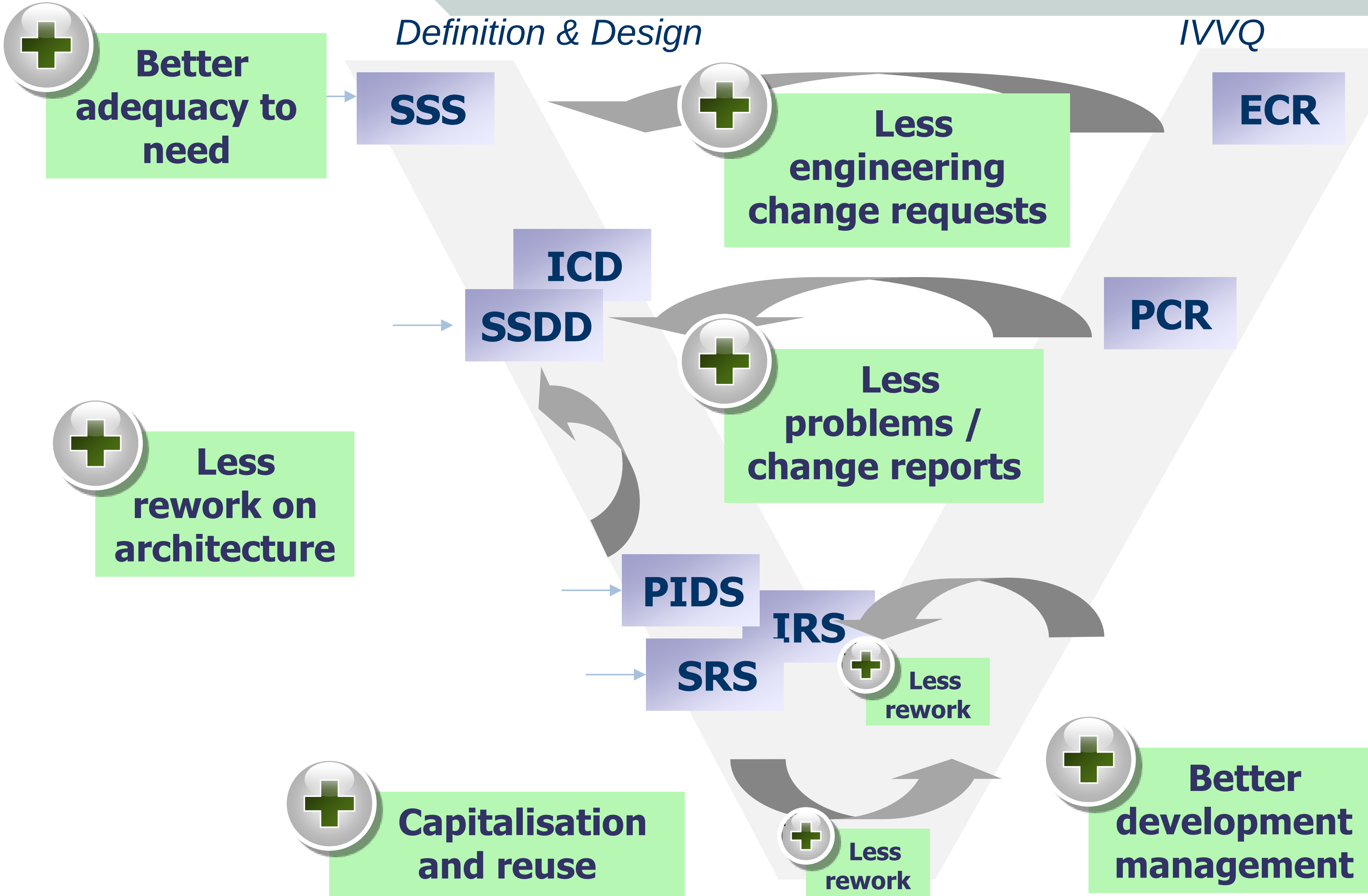
Need evolution

Component delivery delay

Integration trouble…

Non-regression optimisation & mastering

Summary of Expected Benefits



Summary of Contribution to Expected Benefits

Better adequacy to need

Thanks to: Customer Need Analysis *justifying* Architecture

Less engineering change requests

Thanks to: Early Check against Operational Need

Less problems / change reports

Thanks to: Integration Contract + Architecture designed for IVVQ

Less rework on architecture

Thanks to: Early Check of Architecture, non-functional Viewpoints modelling

Better development management

Thanks to: Integration Contract Formalisation

Capitalisation and reuse

Thanks to: Formalised Architecture, Viewpoints & Rules

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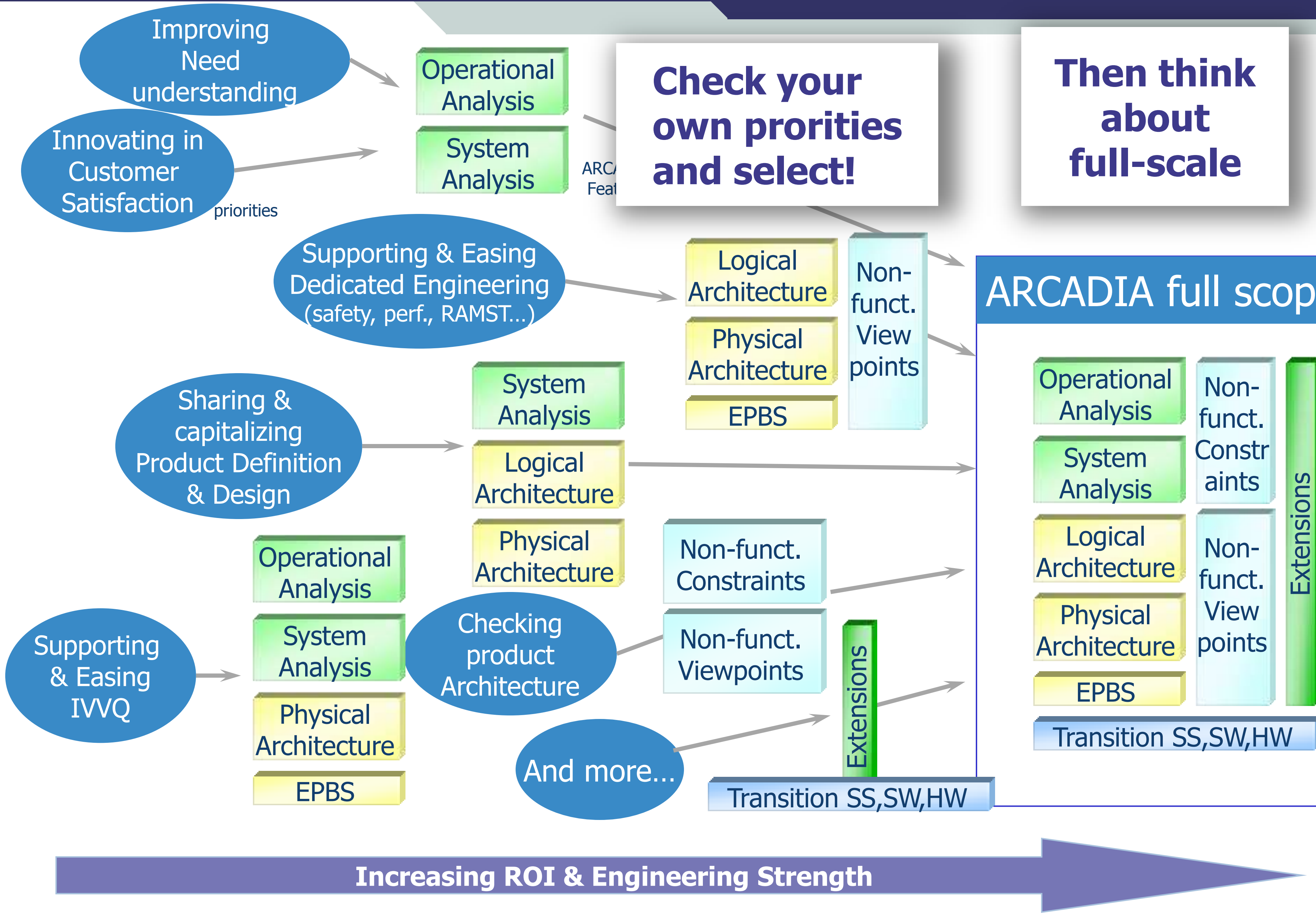
Different purposes & steps in ARCADIA deployment



Some ARCADIA Golden Rules

- Do not model anything if you don't know for what purpose
  - Build models according to the way you will exploit them
  - And according to users / addressees
- Do not model in details if you are not able to keep the model up to date
  - Adjust stopping criteria accordingly
- If you want quick Return on Invest, keep focussed on your major problems / challenges first
- Favor modelling for several usages - "Model once, use many"
  - In order to maximise ROI and motivate for maintenance