



## ENGINEERING KEY QUESTIONS

- How is the customer need received? How are its **consistence and feasibility checked**?
- Which are the **engineering phases in the solution elaboration**, how are they related?
- **How is complexity managed?**
- How are different alternatives evaluated, **how do the specialists collaborate?**
- **How is the solution justified** w.r.t. the need and the different constraints?

## FACTS

- Needs and solutions are more complex, more stakeholders, more constraints, less time
- **The approach Doors / Word / Visio / Excel reaches limits**
- Manual processes are not compatible with agility and short loops



Model-Based Engineering Method for Architectural Design

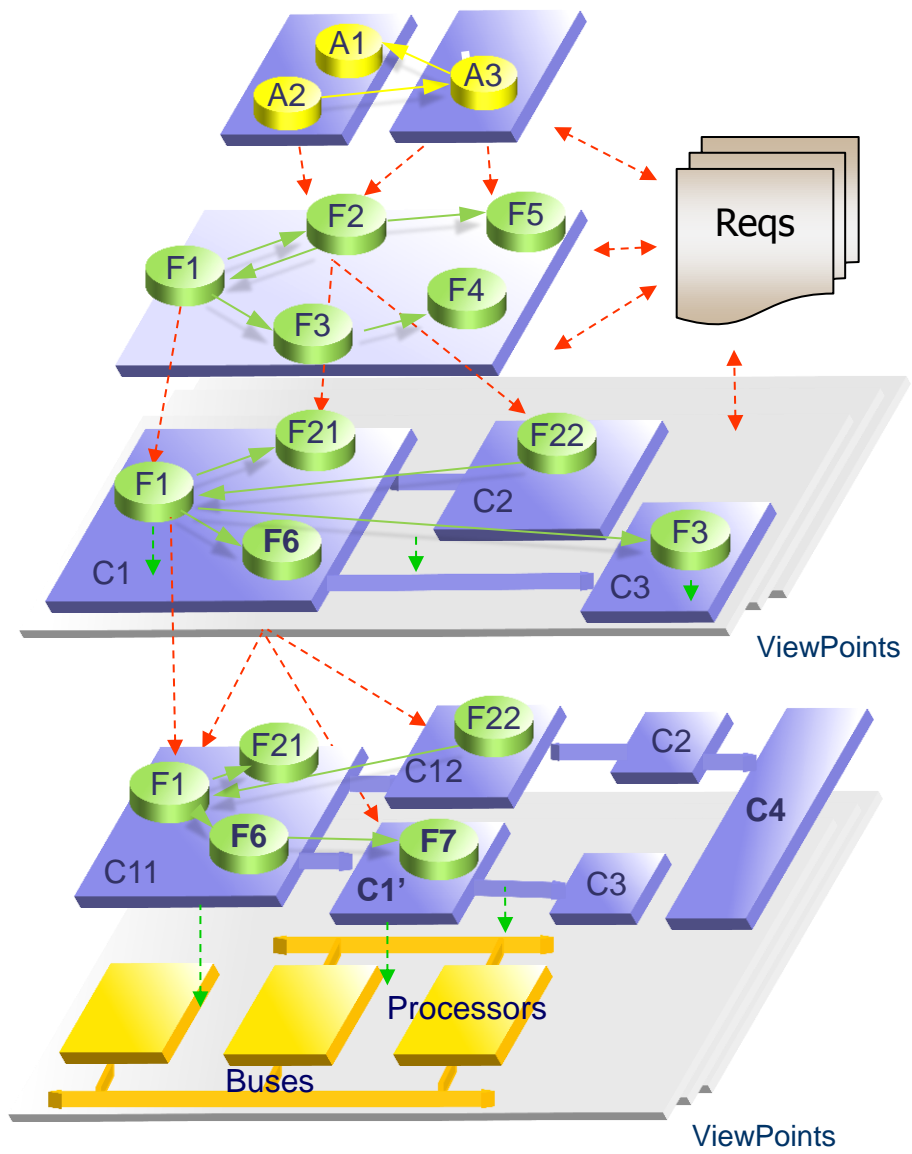


Graphical Modelling Workbench supporting Arcadia



NEED UNDERSTANDING

SOLUTION ARCHITECTURAL DESIGN



What the users of the system need to accomplish

What the system has to accomplish for the users

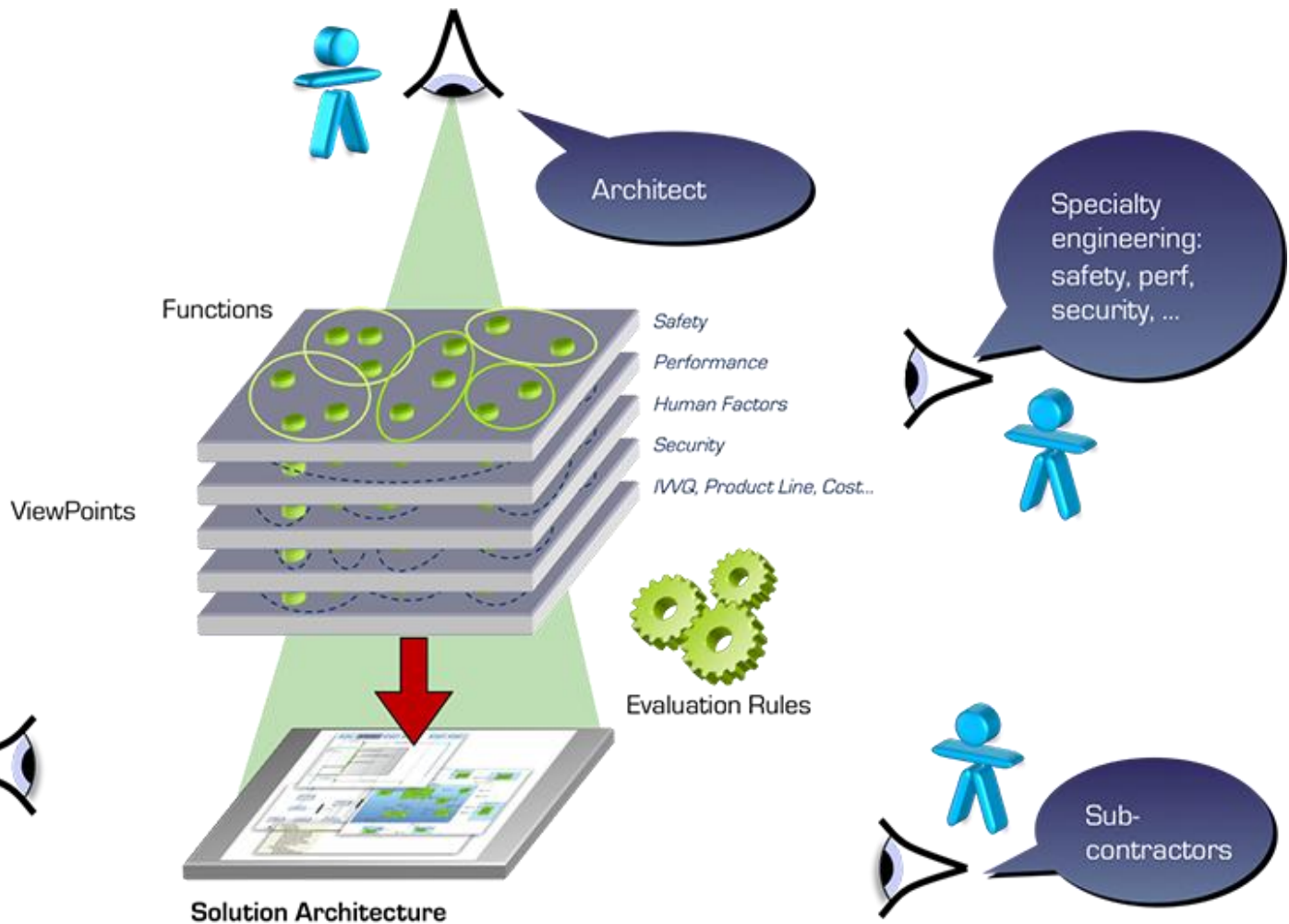
How the system will work to fulfill expectations

How the system will be developed and built

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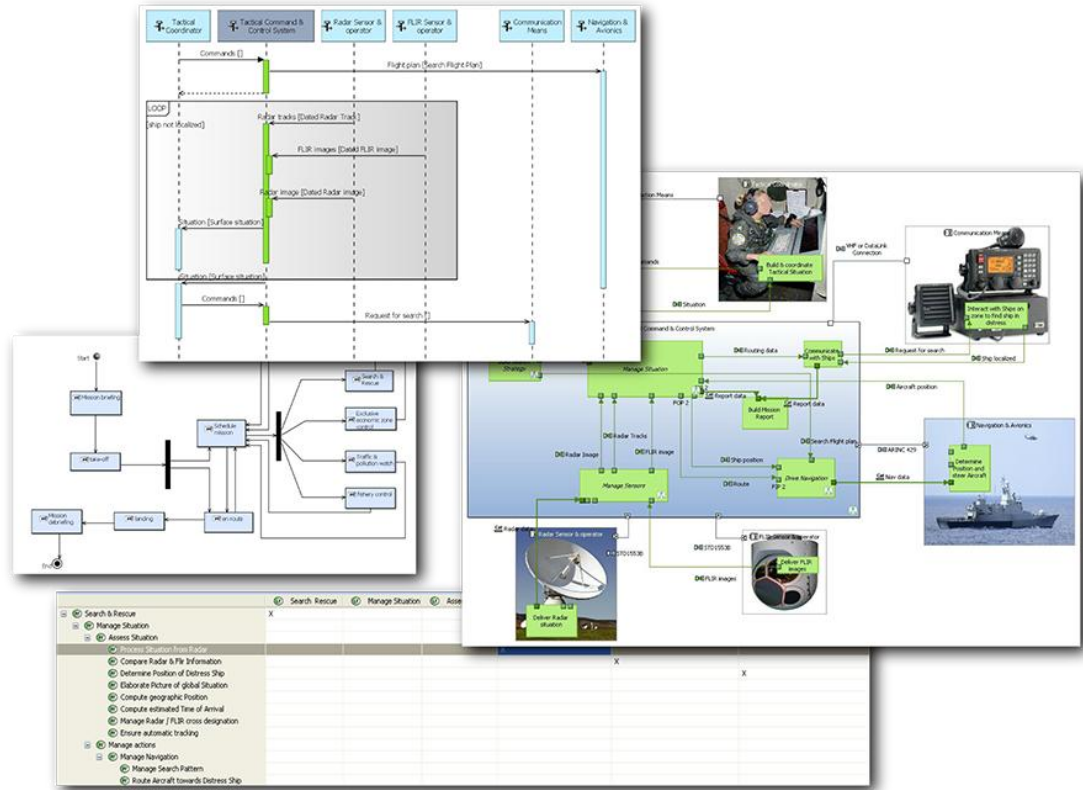
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- Guidance**  
 [Embedded methodological browser]
- Complexity management**  
 [Abstraction via computed information]
- Productivity tools**  
 [Automated transitions and diagram creation accelerators]
- Model Analysis & Navigation**  
 [Model validation, semantic browser]
- Multi-criteria analysis**  
 [Viewpoints and management framework]




# Capella

First operational deployments in 2009

Used on most major engineering projects

Open sourced in 2014

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Melody Advance - platform:/resource/SAR/SAR.air.d/[PAB] Implementation Vs Behavioral - Processing(Physical Component Physical System) - Melody Advance

File Edit Diagram Navigate Search Project Run Window Help

SAR - Overview

## Overview of SAR

**Operational Analysis**

**Define Stakeholder Needs and Environment**

Capture and consolidate operational needs from stakeholders  
Define what the users of the system have to accomplish  
Identify entities, actors, roles, capabilities, activities, concepts

**System Analysis**

**Formalize System Requirements**

Identify the boundary of the system, consolidate requirements  
Define what the system has to accomplish for the users  
Model functional dataflows and dynamic behaviour

**Logical Architecture**

**Develop System Logical Architecture**

See the system as a white box: define how the system will work so as to fulfill expectations  
Perform a first trade-off analysis

**Physical Architecture**

**Develop System Physical Architecture**

How the system will be developed and built  
Software vs. hardware allocation, specification of interfaces, deployment configurations, trade-off analysis

**EPBS**

**Formalize Component Requirements**

Manage industrial criteria and integration strategy: what is expected from each designer / sub-contractor  
Specify requirements and interfaces of all configuration items

Doors Management - Overview

## Physical Architecture

Logical Architecture → **Physical Architecture** (Develop System Architectural Design) → EPBS

Transition from Logical Functions

- Perform an automated transition of Logical Functions
- Create Traceability Matrix

Refine Physical Functions, describe Functional Exchanges

- [PFBD] Create a new Functional Breakdown diagram
- [PDFB] Create a new Functional Dataflow Blank diagram
- [FS] Create a new Functional Scenario

Define Physical Components and Actors, Manage deployments

- Perform an automated transition of Logical Actors
- Perform an automated transition of Logical Components
- [PCBD] Create a new Physical Component Breakdown diagram
- [PAB] Create a new Physical Architecture diagram
- Create a new Physical Component / Logical Component Matrix

Allocate Physical Functions to Physical Components

Delegate Logical Interfaces and create Physical Interfaces

Enrich Physical Scenarios

[OIS] Doors closing Scenario(Scenario Scenario)

[PAB] Implementation Vs Behavioral - Processing(Physical Component Physical System)

Introduction | Operational Analysis | System Analysis | Logical Architecture | **Physical Architecture** | EPBS

128M of 762M



## Use Case 1: Managing System Design Complexity

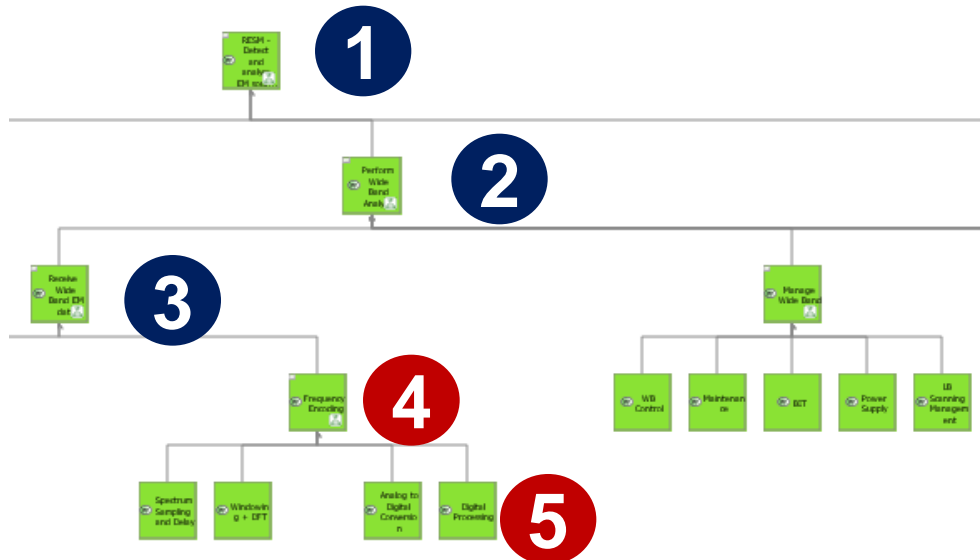
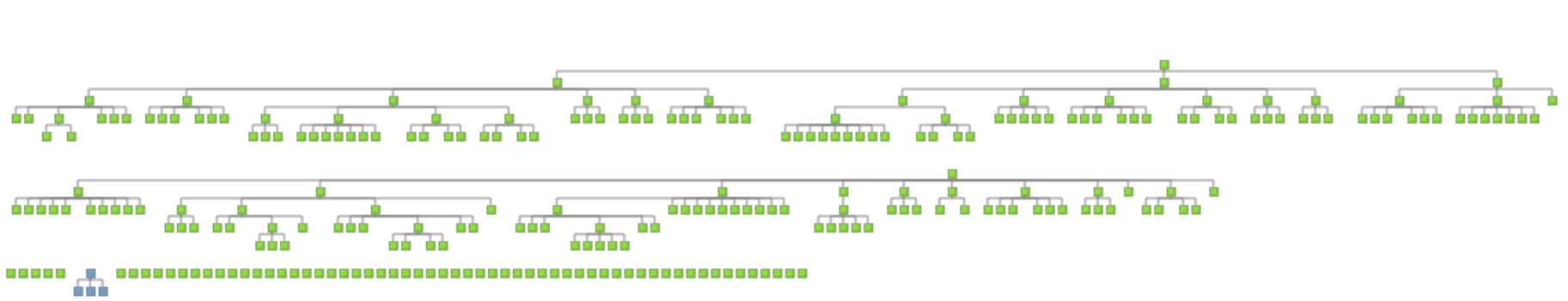


## Context



## MBSE usage

- Issues in the latest phases of operational validation
  - Very good design documents, but in silos
- 
- 1 man month to **reverse a first level of detail** in a model, based on existing documents
  - **First time overall views have been available**
    - Good support for discussion
    - Visualization of transverse functional chains



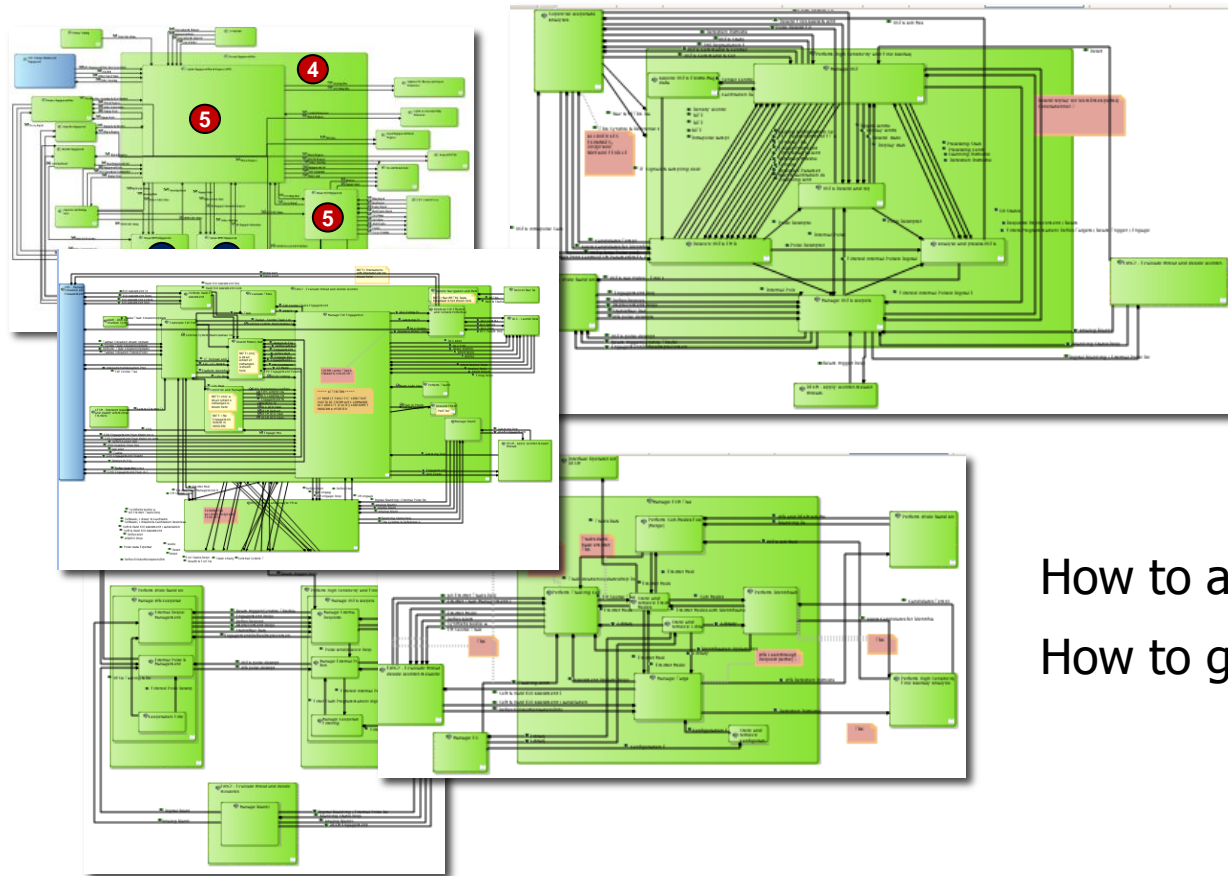
**275** Functions  
(230 Leaves)

**578** Functional  
Exchanges between leaf  
functions

**5** levels of decomposition

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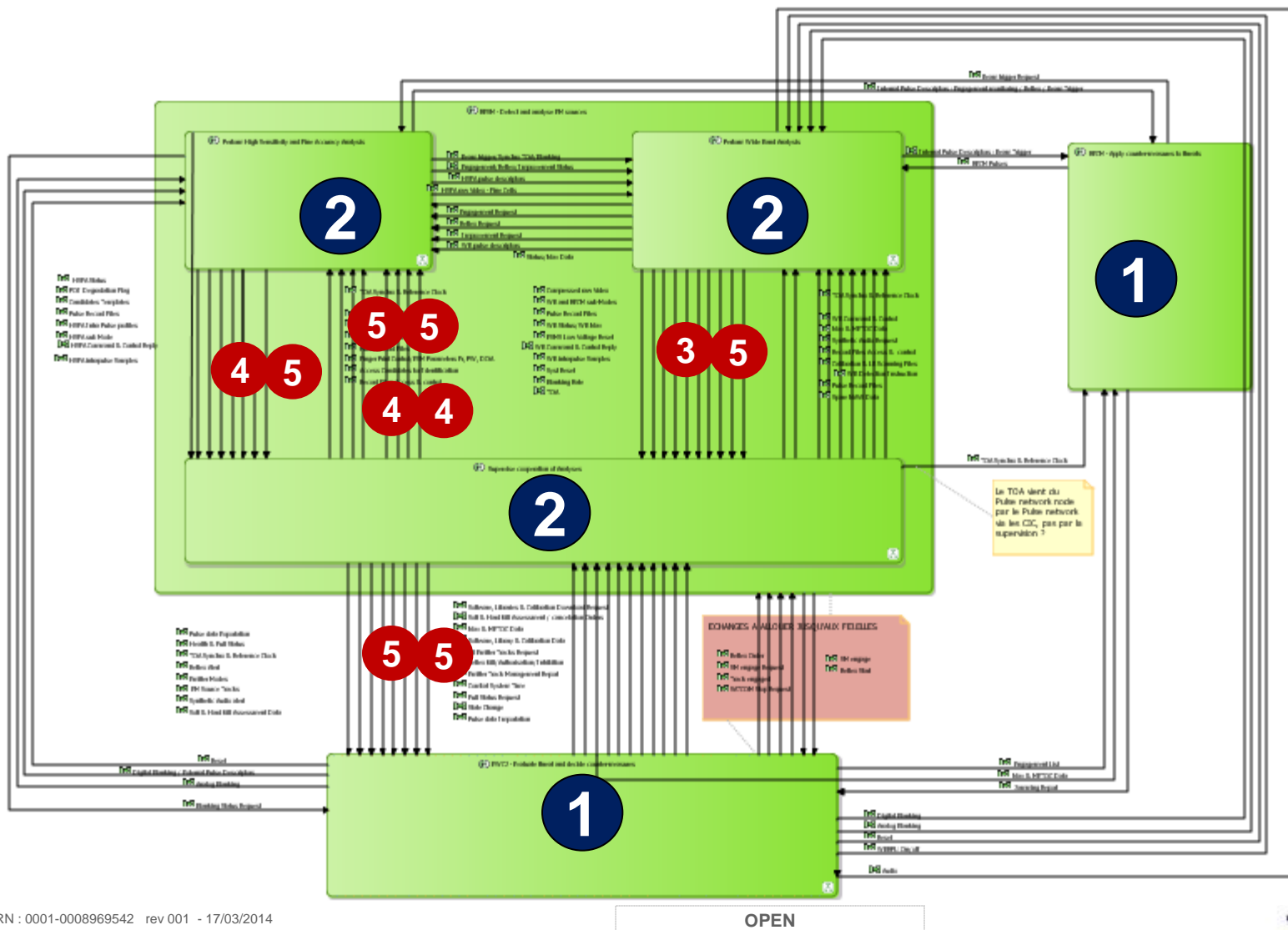


# X 40

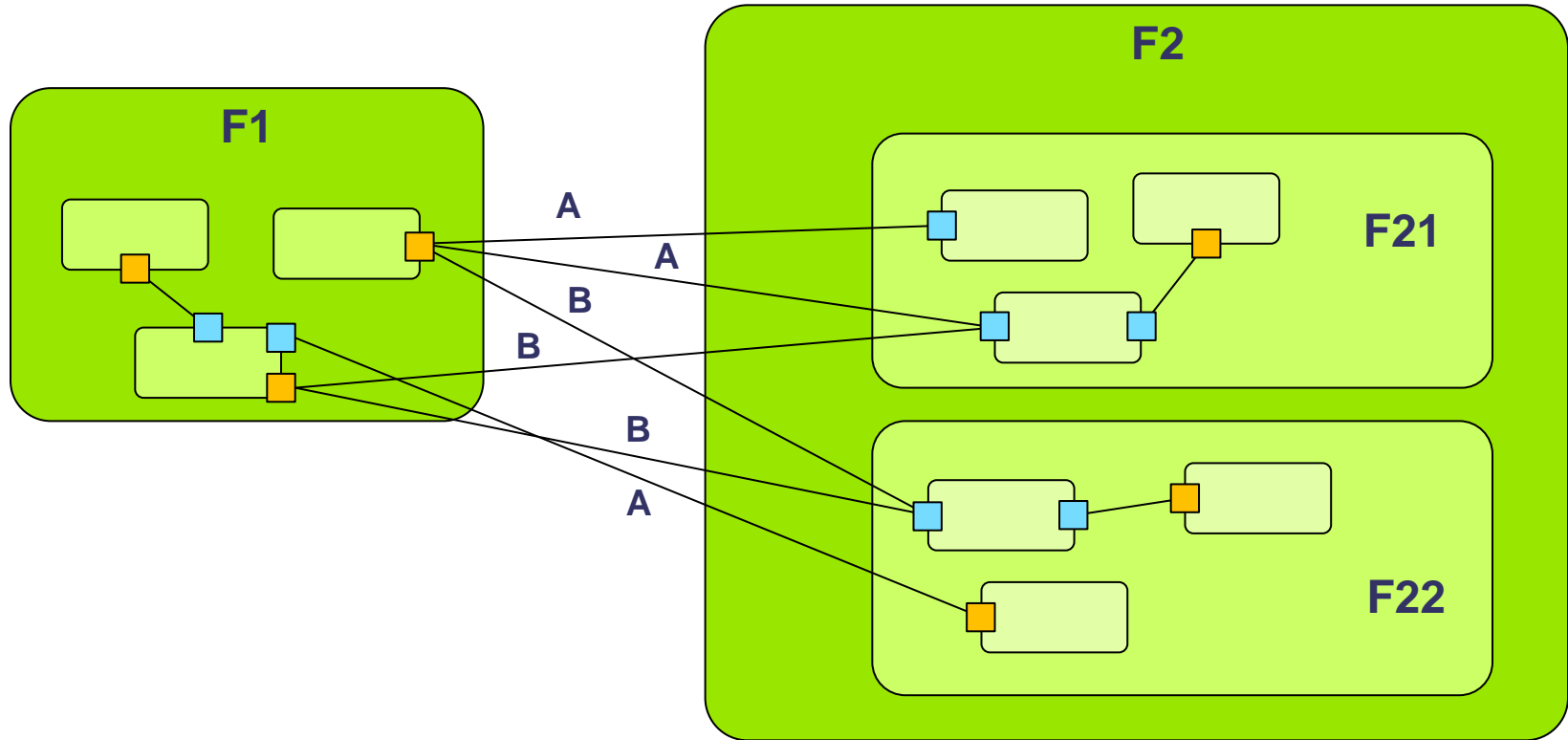
How to analyze transverse topics?  
How to get transverse overviews?

**Challenge: Build and maintain simplified views**

## Computed Diagrams: High-level Functions, Low-level Exchanges



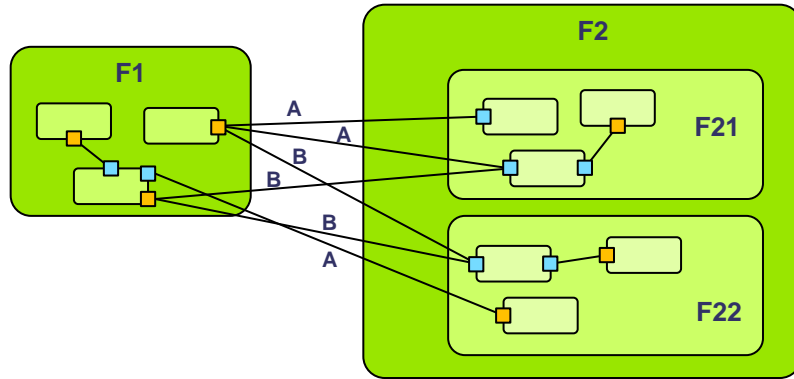
## MODEL



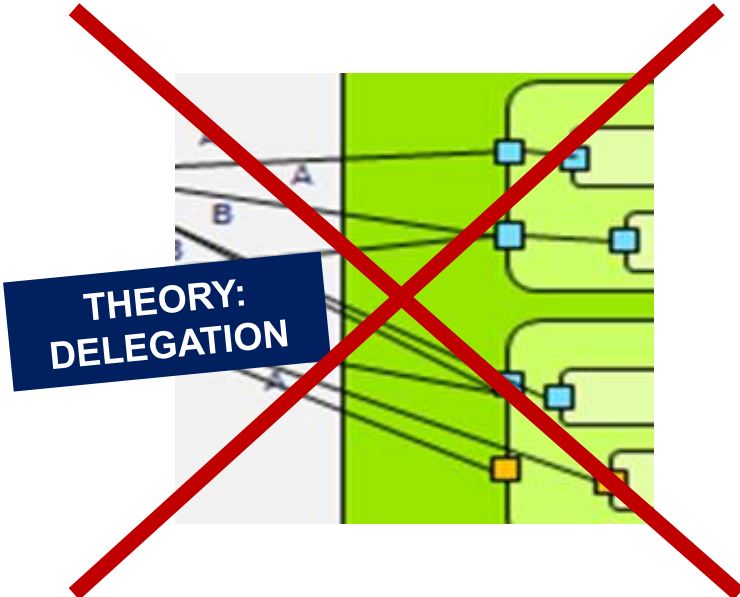
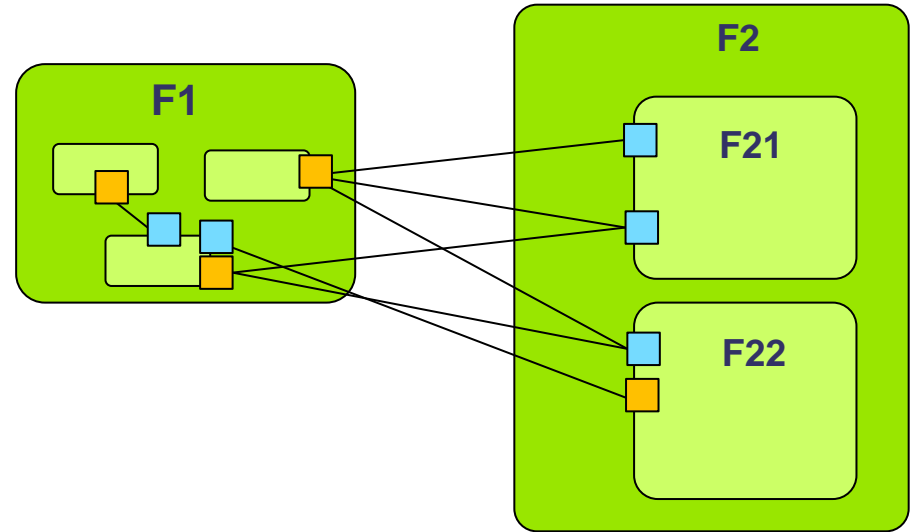
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## MODEL



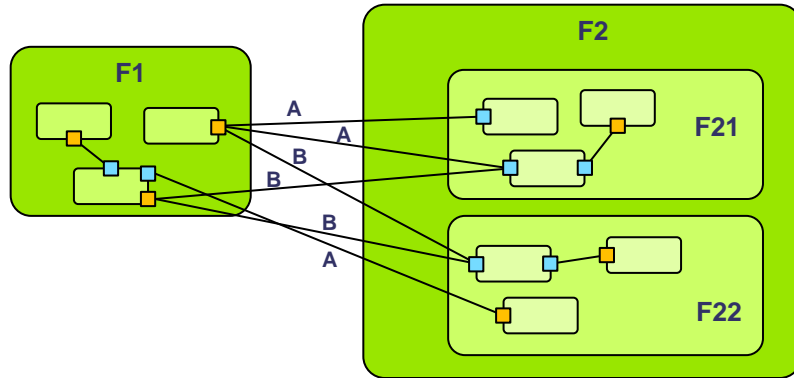
## VIEW



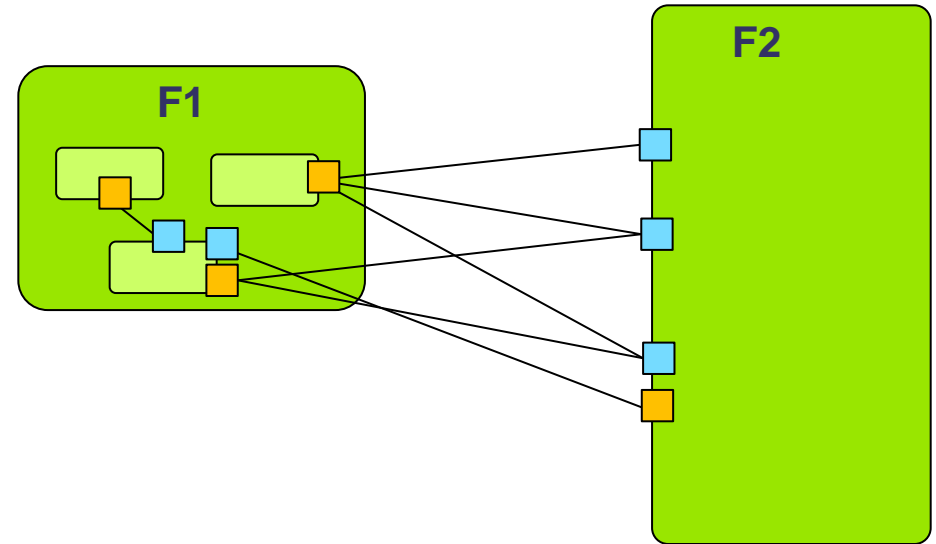
Children of F21 and F22 not displayed

Ports on F21 and F22 are graphically computed (they actually belong to the children of F21 and F22)

## MODEL



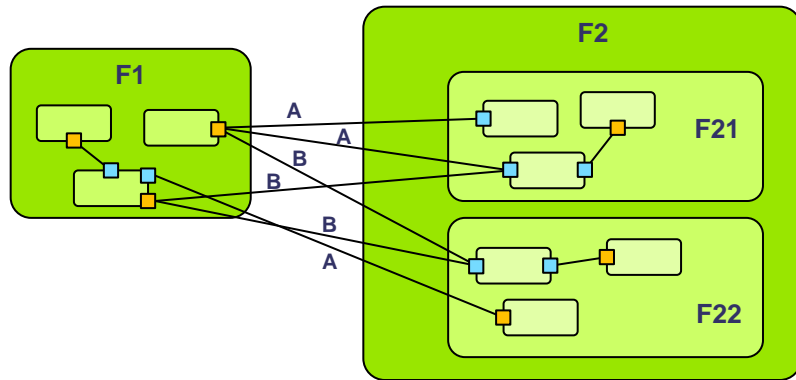
## VIEW



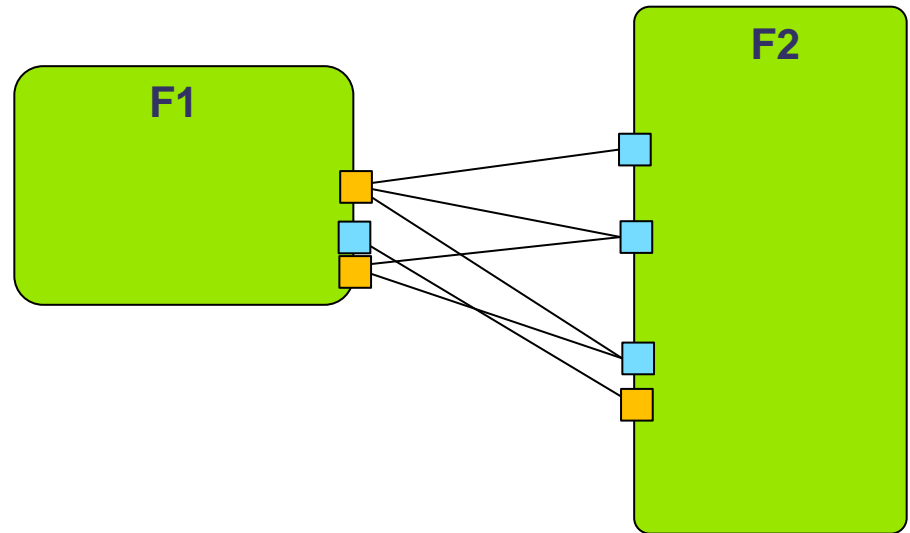
Children of F2 not displayed

Ports on F2 are graphically computed  
(they actually belong to the children of  
F21 and F22)

## MODEL



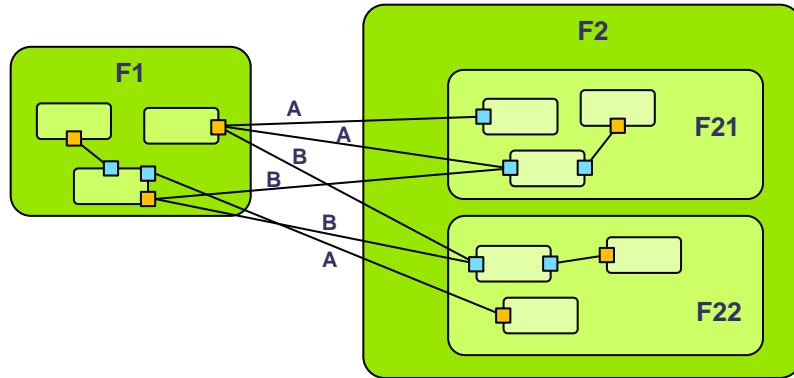
## VIEW



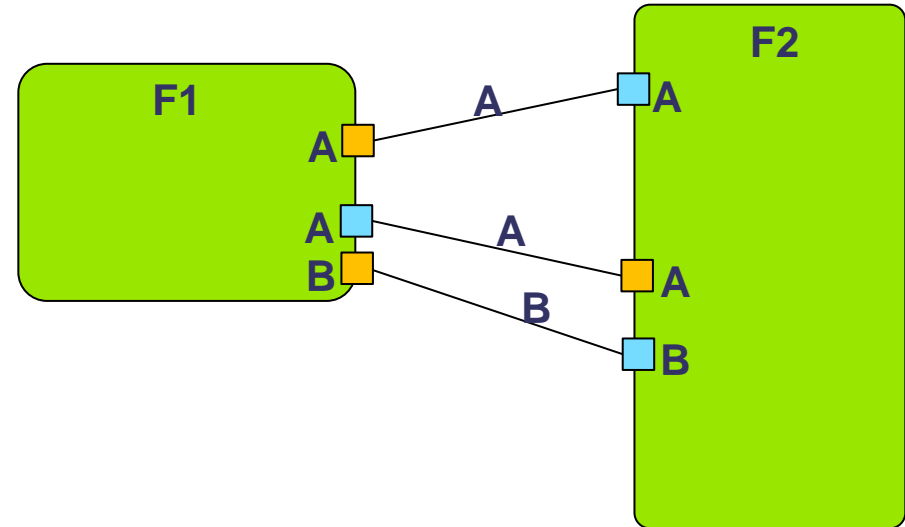
Children of F1 and F2 not displayed

Ports on F1 and F2 are graphically computed (they actually belong to the children of F21 and F22)

## MODEL



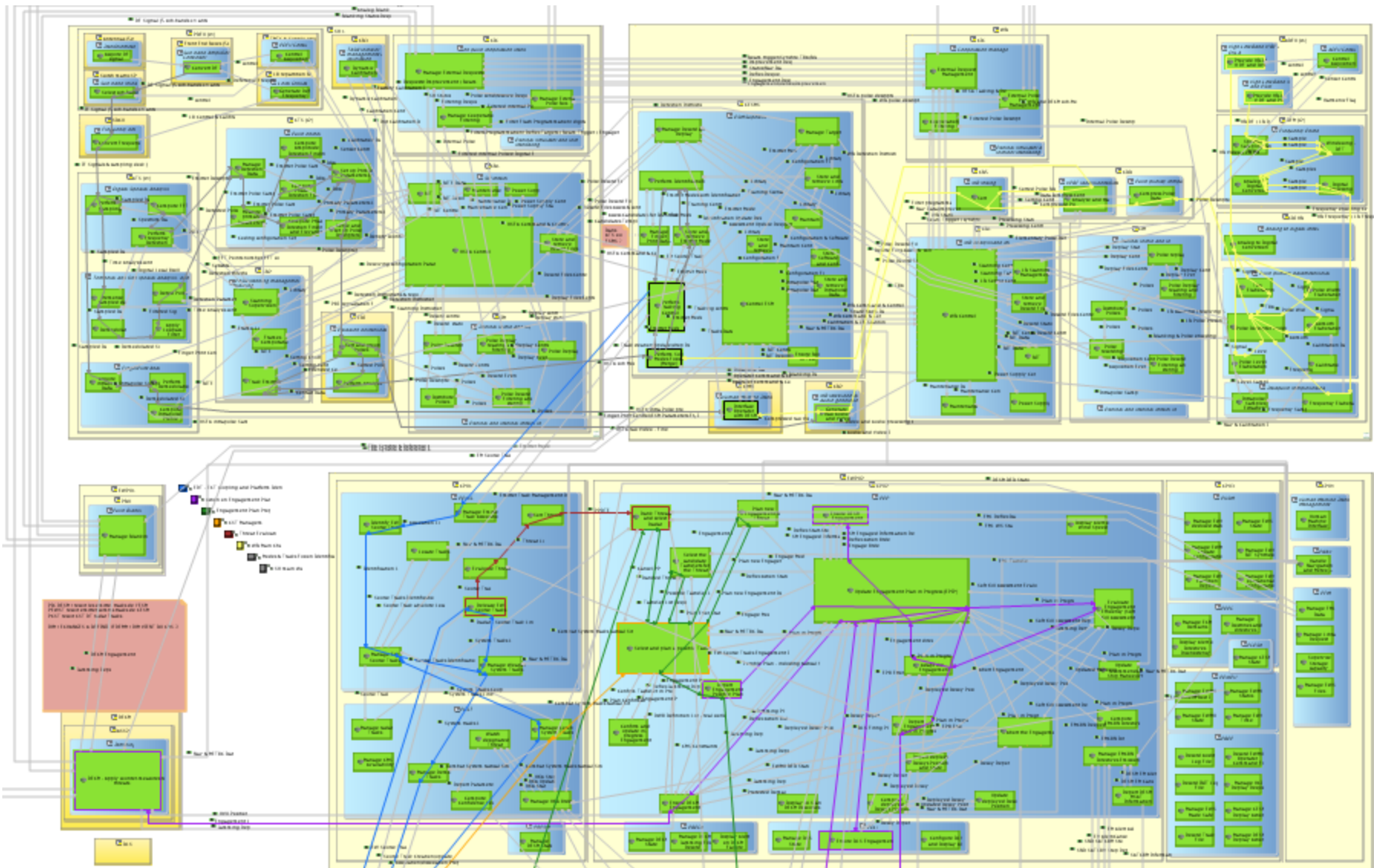
## VIEW



Tag-based simplification mechanism:  
each exchange can be marked with  
several « grouping » tags

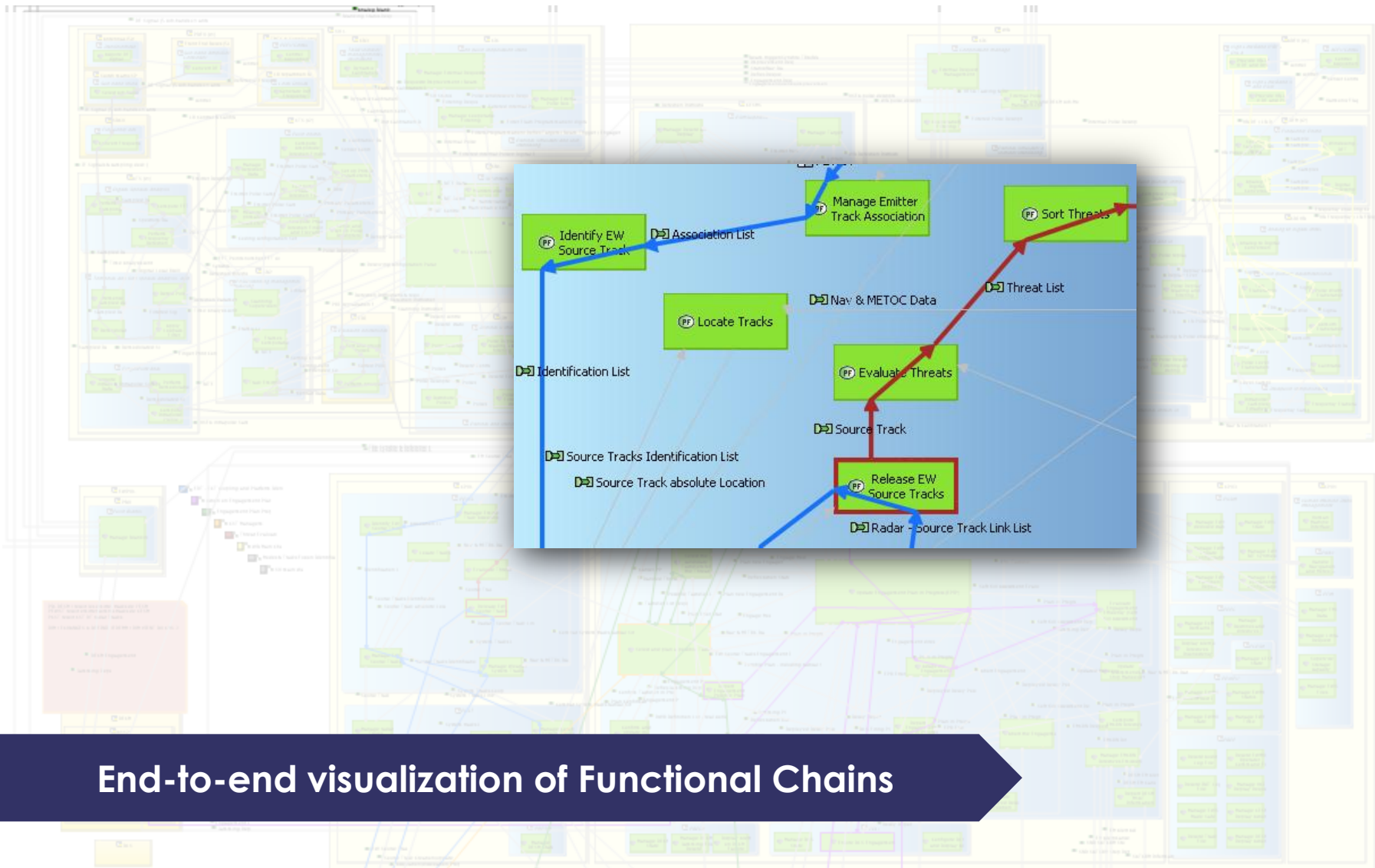
**Computed graphical simplifications free engineers from tedious and error-prone maintenance of abstraction levels**

# Managing System Design Complexity: Global Overview



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**End-to-end visualization of Functional Chains**





## Use Case 2:

# MBSE-based Change Management

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## Context



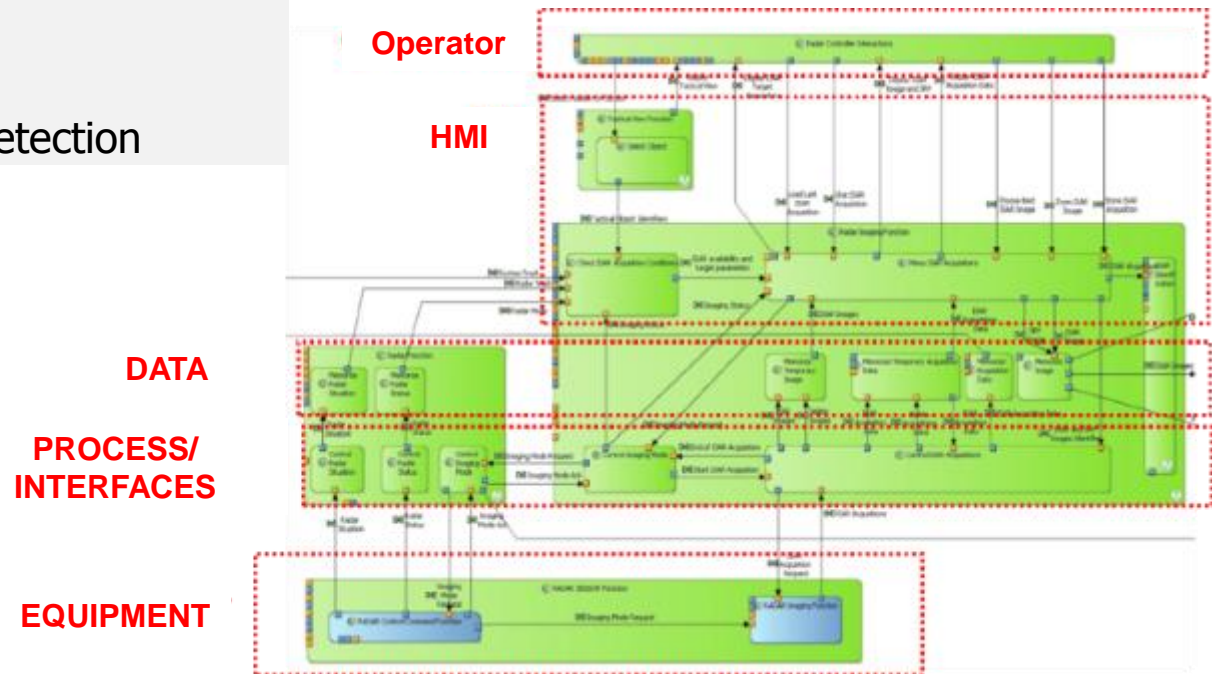
## MBSE usage

- Maritime Patrol Program delivered to the Customer
- New functionalities asked by the Customer

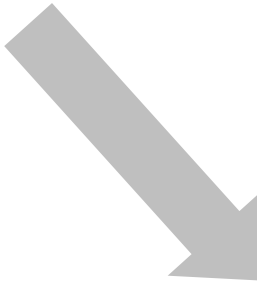
- Up-to-date model of the delivered System available
- Modification of the model in order to:
  - **Estimate feasibility, cost and risks**
  - Drive developments and IVVQ
- **Product line** management

## A regular layout / reading pattern across all diagrams

- Multiple contributors modelling the same way
- Facilitates first access to diagrams
- Eases diagram review
- Allows quick inconsistency detection

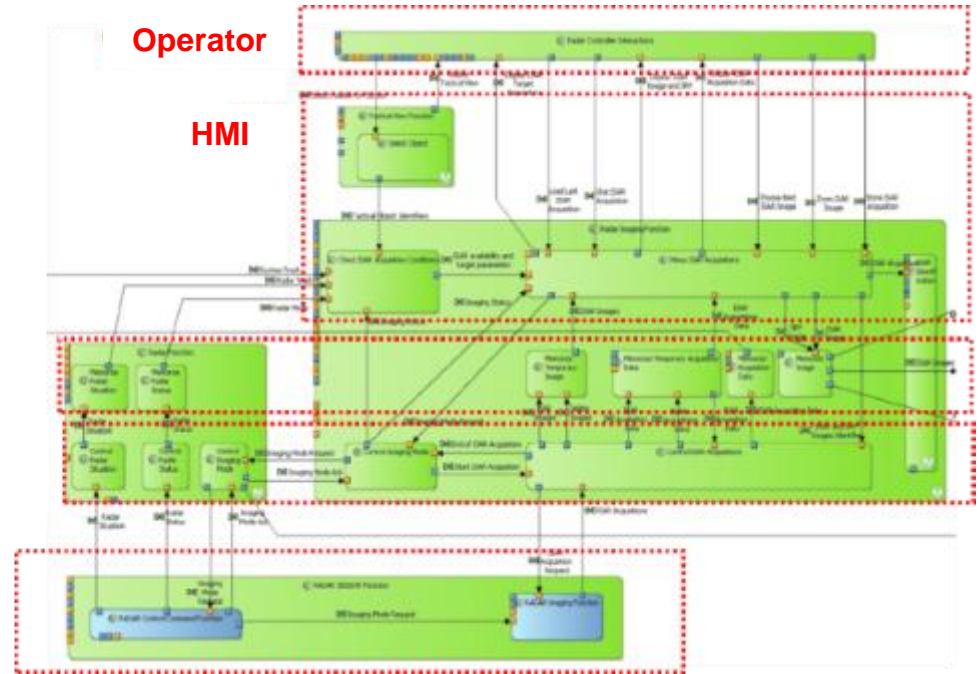


SSS: Need



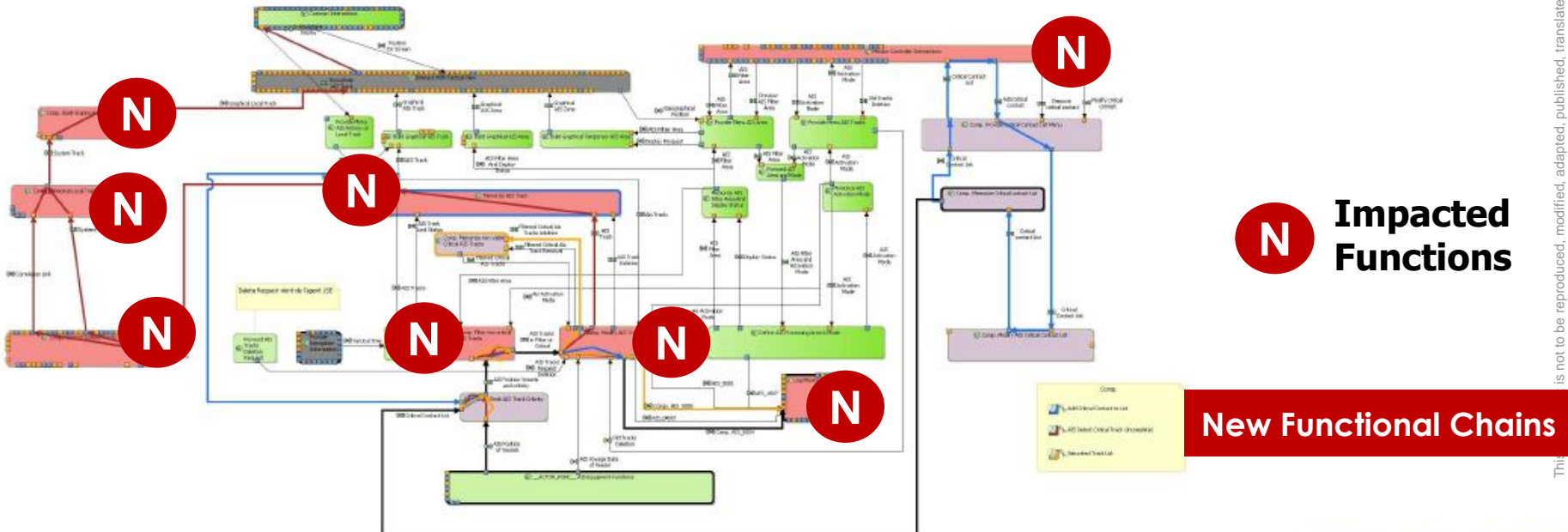
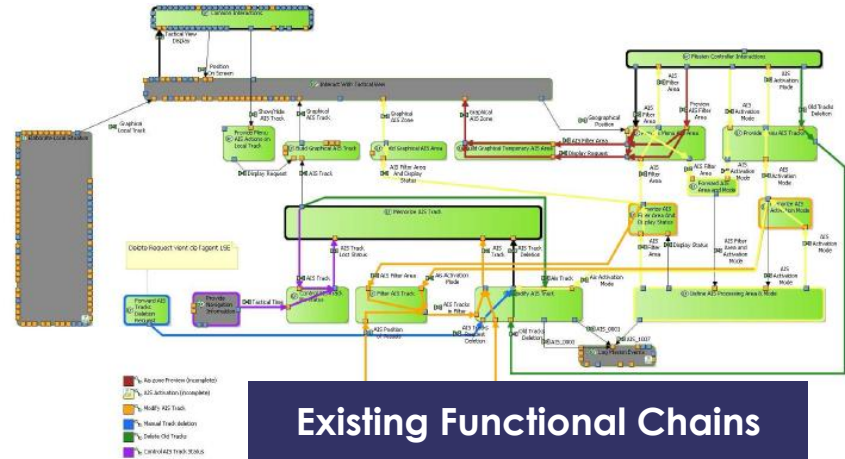
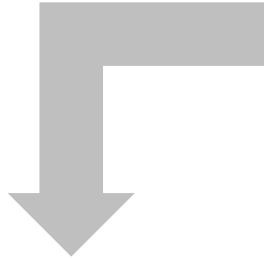
PIDS: Reverse Engineering from Software Specification

**DATA**  
**PROCESS/  
INTERFACES**  
**EQUIPMENT**



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## New Customer needs



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## COST Analysis Viewpoint

Elementary work decomposition, and estimation of an average development cost for each category of function

- Panels
- External / Internal Interfaces
- Data Memorisation
- Processing Complexity

## Computed Data: Estimated Cost

## Capella Outputs (model export)

DEF	GHI	J	K	N	O	P	Q	R	AI	AJ	AK	AL	AM	AP	AQ	AR
			<b>Fct 9</b>	Panneaux OM ou	Interfaces internes	Interfaces externes	Memorisation	Ion: 1 st	Algo: Niveau 1=	Complexité	Complexité	Complexité	Complexité			
				528	1485	82	45	697		238	238	13650				
				800	1300	70	50	400		239	239	14843		New	77%	
				7	2	5	2	10		1	###			Reuse	15%	0
				<b>Totaux</b>	<b>528</b>	<b>1485</b>	<b>82</b>	<b>45</b>	<b>697</b>	<b>234</b>	<b>238</b>	<b>16009</b>	<b>13912</b>	<b>COTS</b>	<b>8,4%</b>	<b>9419</b>
				1	3	0	0	5		1	1	69	69	New	100%	69
				0	3	0	0	1		1	1	20	20	New	100%	20
				0	4	0	1	0		1	1	18	18	New	100%	18
										0						
										0						
				3	15	0	0	2		2	1	101	101	New	100%	101
				0	11	0	1	0		1	1	32	32	New	100%	32
				2	8	0	0	4		2	1	96	96	New	100%	96
				2	8	0	0	2		2	1	70	70	New	100%	70
				0	2	0	0	2		1	1	30	30	New	100%	30
										0						
				4	9	0	0	0		1	1	57	57	New	100%	57
				0	5	0	0	0		0	1	10	10	New	100%	10
										0						
				0	4	0	0	0		0	1	14	14	New	100%	14
				0	9	0	1	0		1	1	31	31	New	100%	31
				2	3	0	0	0		0	1	20	20	New	100%	20
										0						
				0	6	0	1	0		1	1	17	17	New	100%	17
				0	6	0	1	0		1	1	17	17	New	100%	17
				0	8	0	1	0		1	1	23	23	Reuse	75%	17
				4	8	0	0	5		1	1	103	103	COTS	50%	52
				0	5	0	0	0		0	1	10	10	New	100%	10

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## Use Case 3: Multi-Level Engineering

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## Context

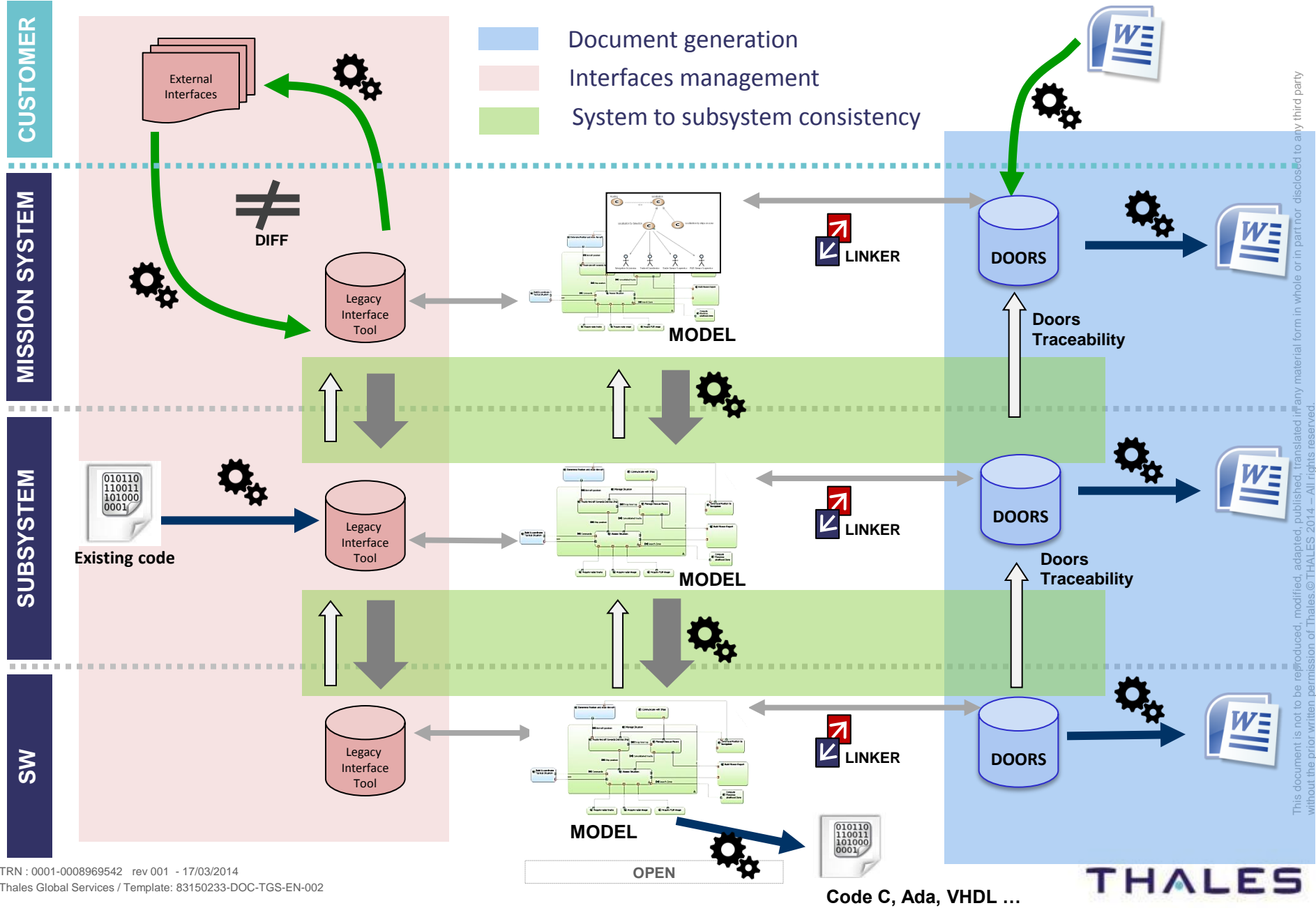


## MBSE usage

- Complex systems with full Thales responsibility (from Mission System to SW Component)

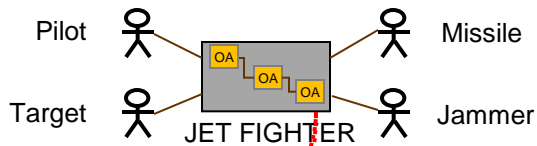
- Setup a global, **multi-level engineering approach**
- Joint effort with Thales Airborne Systems / Thales Corporate to **specify and develop an automated, iterative transition**
- Incubation on two projects
- Now integrated in the product and used in other contexts

# Multi-Level Engineering and Automated Transitions

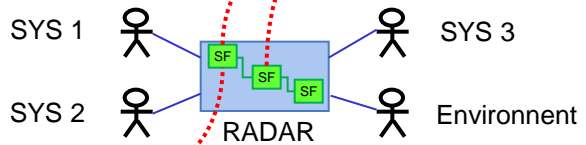


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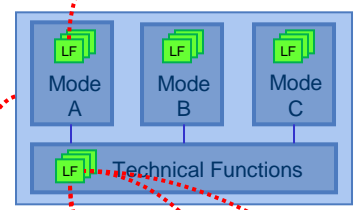
## Operational Analysis



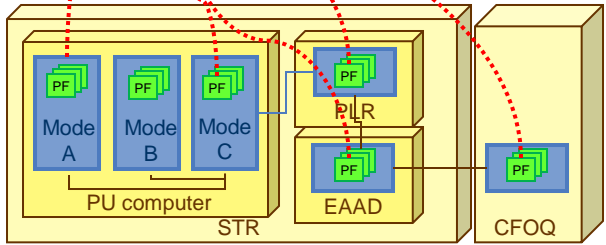
## System Analysis



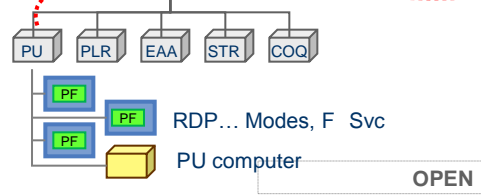
## Logical Architecture



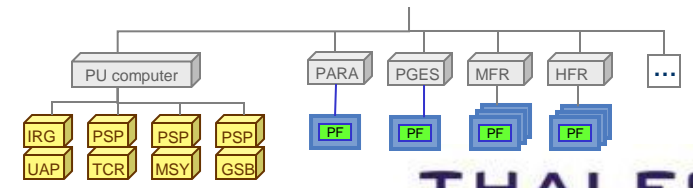
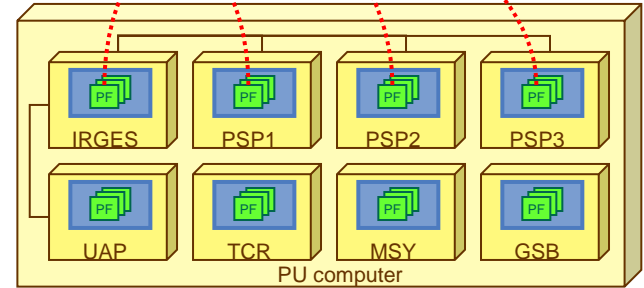
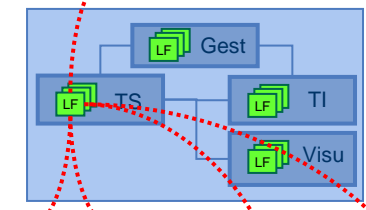
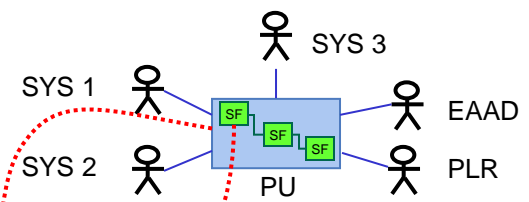
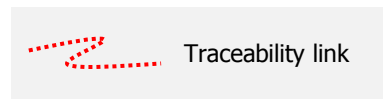
## Physical Architecture



## Product Breakdown Structure

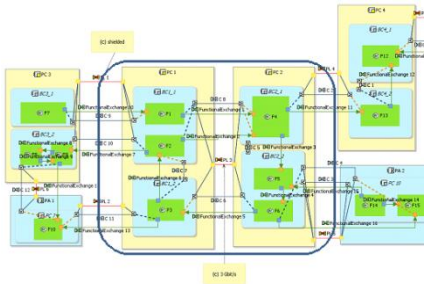


## Processing Unit Engineering

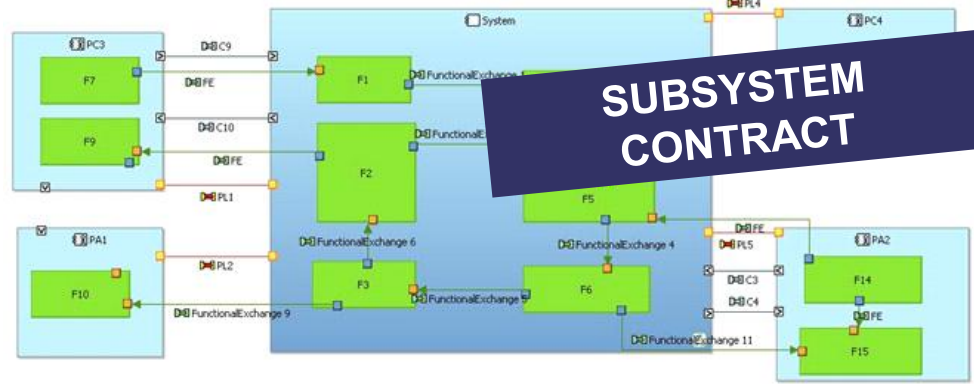
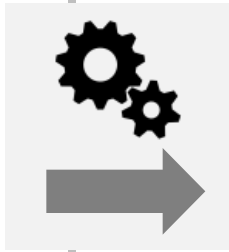


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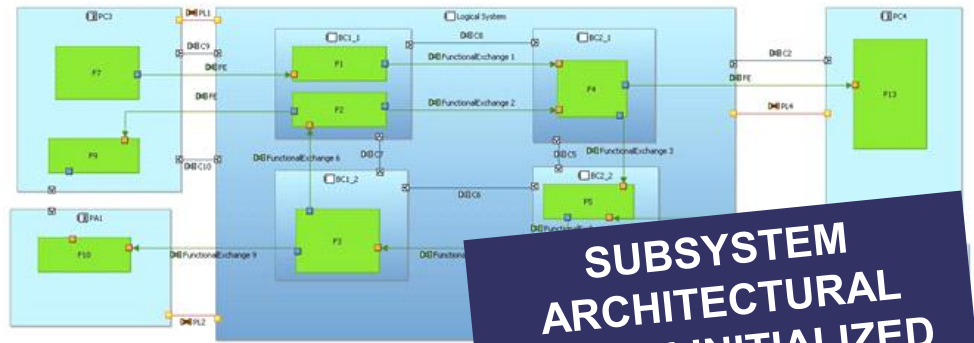
## System Physical Architecture



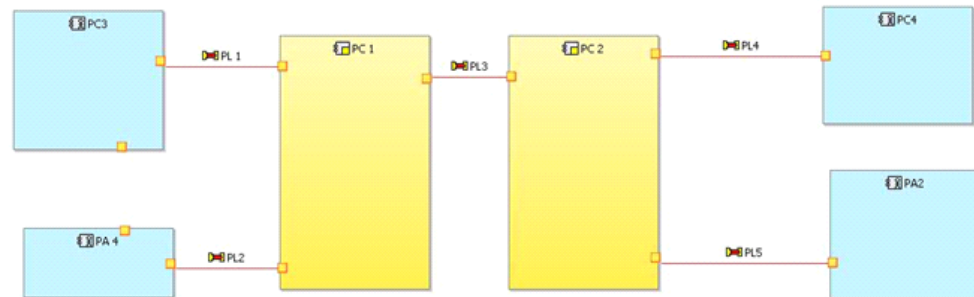
## Subsystem Need Analysis



## Subsystem Logical Architecture



## Subsystem Physical Architecture



**CO-ENGINEERING**

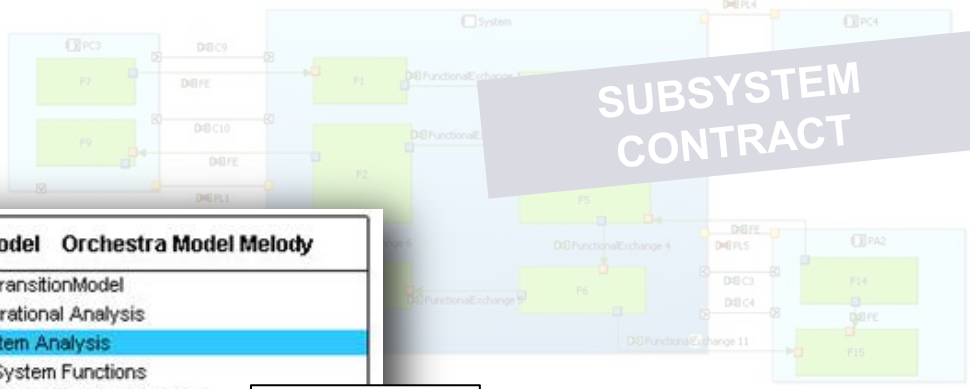
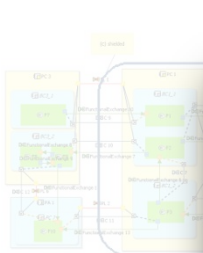
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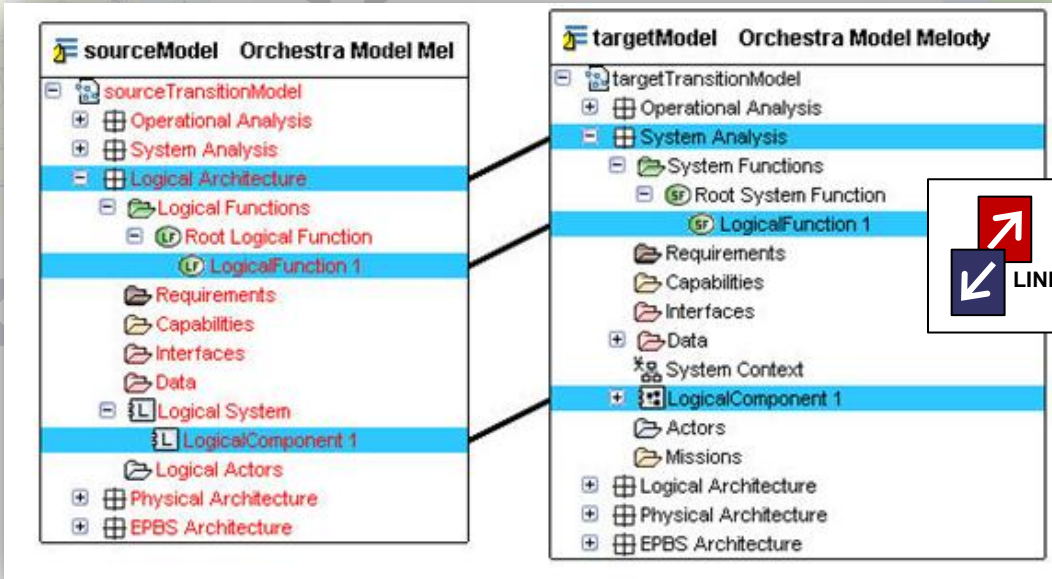
System Physical Architecture

Subsystem Need Analysis



**SUBSYSTEM CONTRACT**

CO-EN



**LINKER**

**SUBSYSTEM ARCHITECTURAL DESIGN INITIALIZED**

Subsystem Physical Architecture



**Computed system - subsystem traceability**

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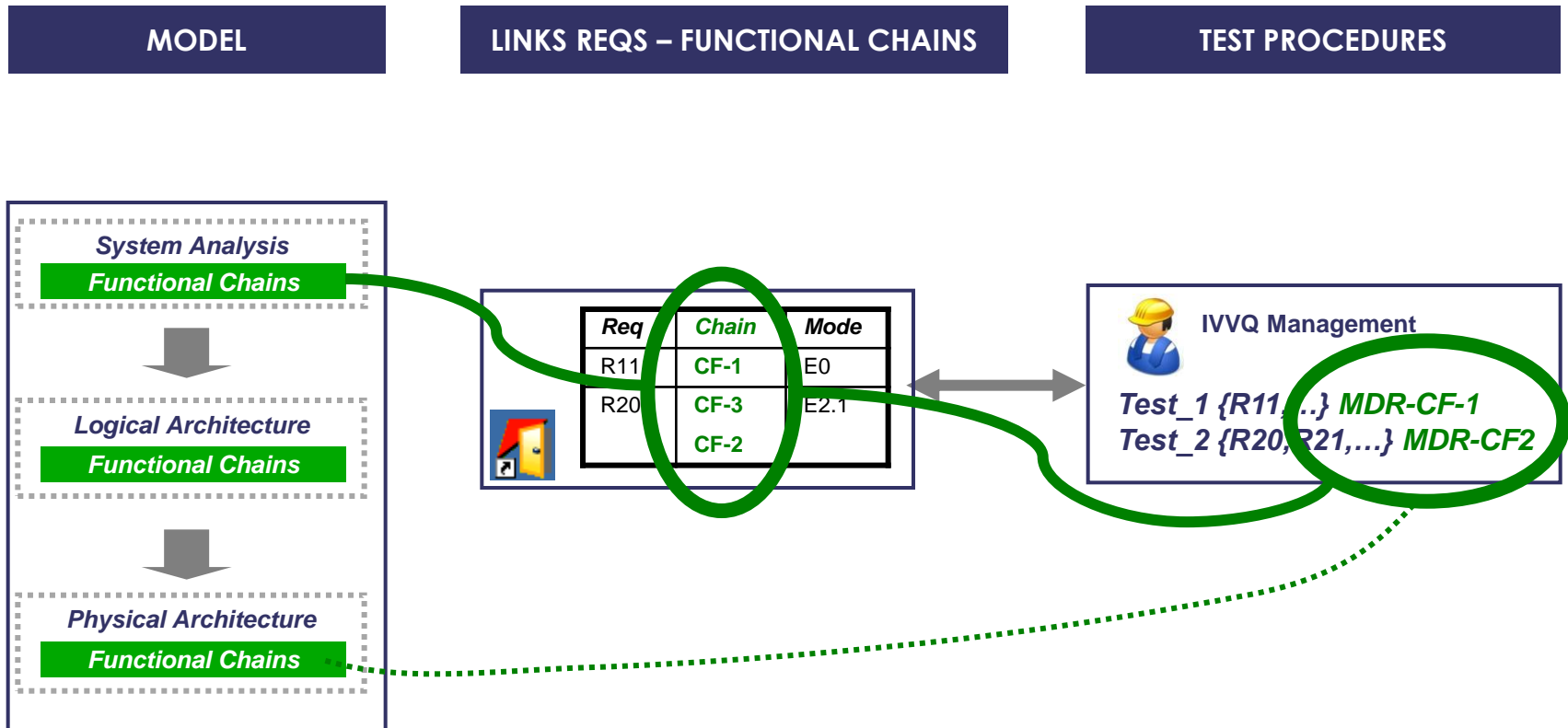




## Use Case 4: Model-driven IVV

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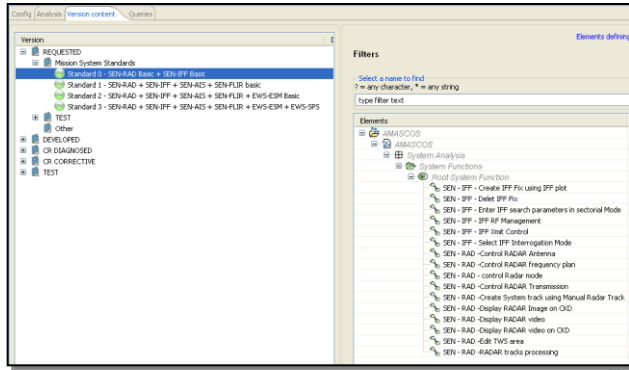


Requirements are clarified with Functional Chains

Test Procedures are linked to Functional Chains

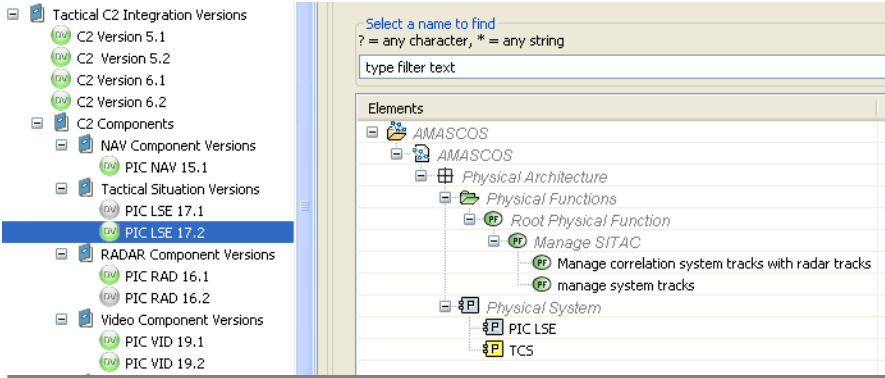
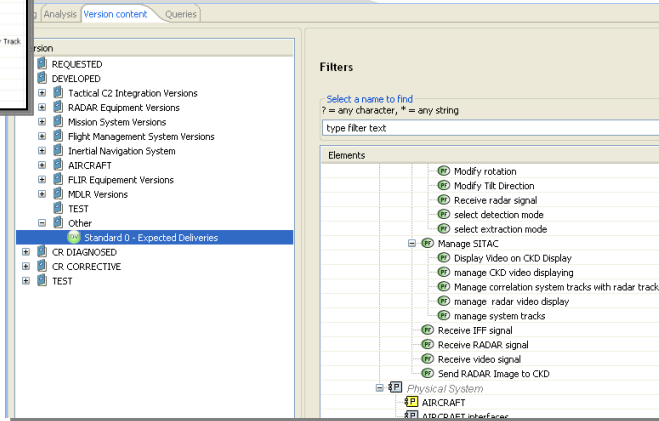


# IVV Strategy: Requested Versions / Developed Versions



Define operational content expected for each project milestone

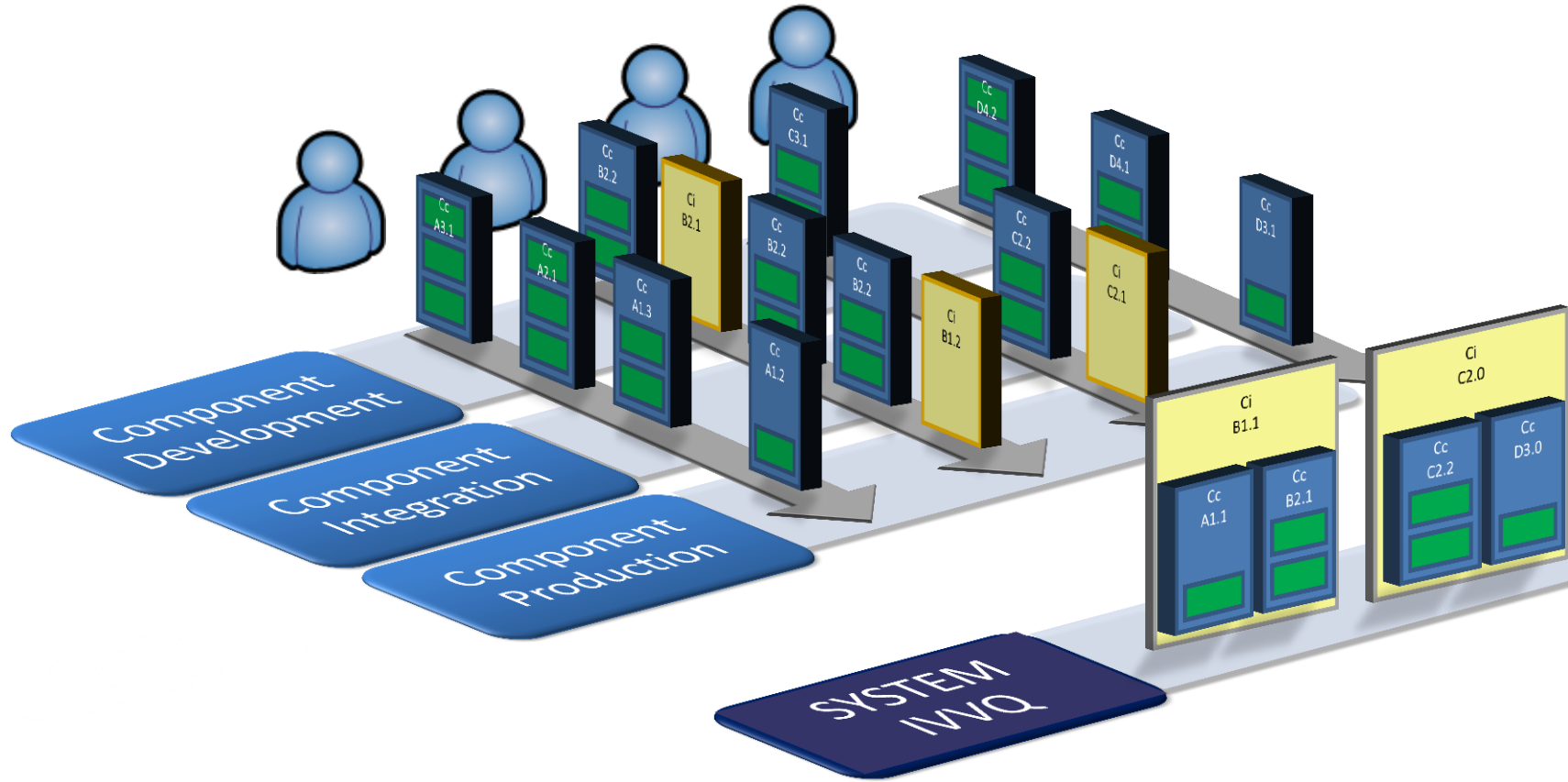
Deduce functional content and components to be delivered



Define components versions and content

Based on an (non open source) IV&V viewpoint on top of Capella

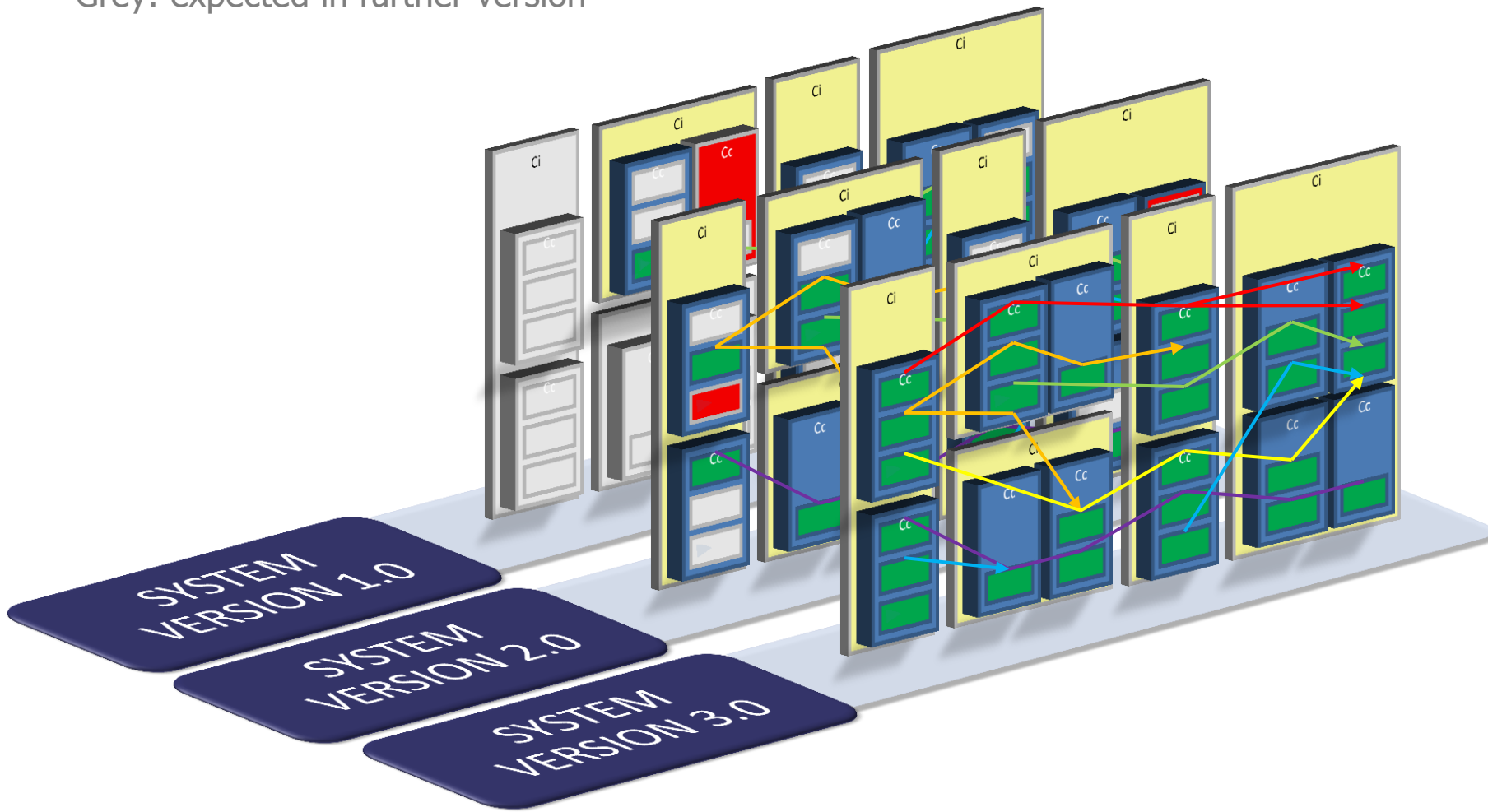
Blue: Software  
Yellow: hardware



**Based on an (non open source) IV&V viewpoint on top of Capella**

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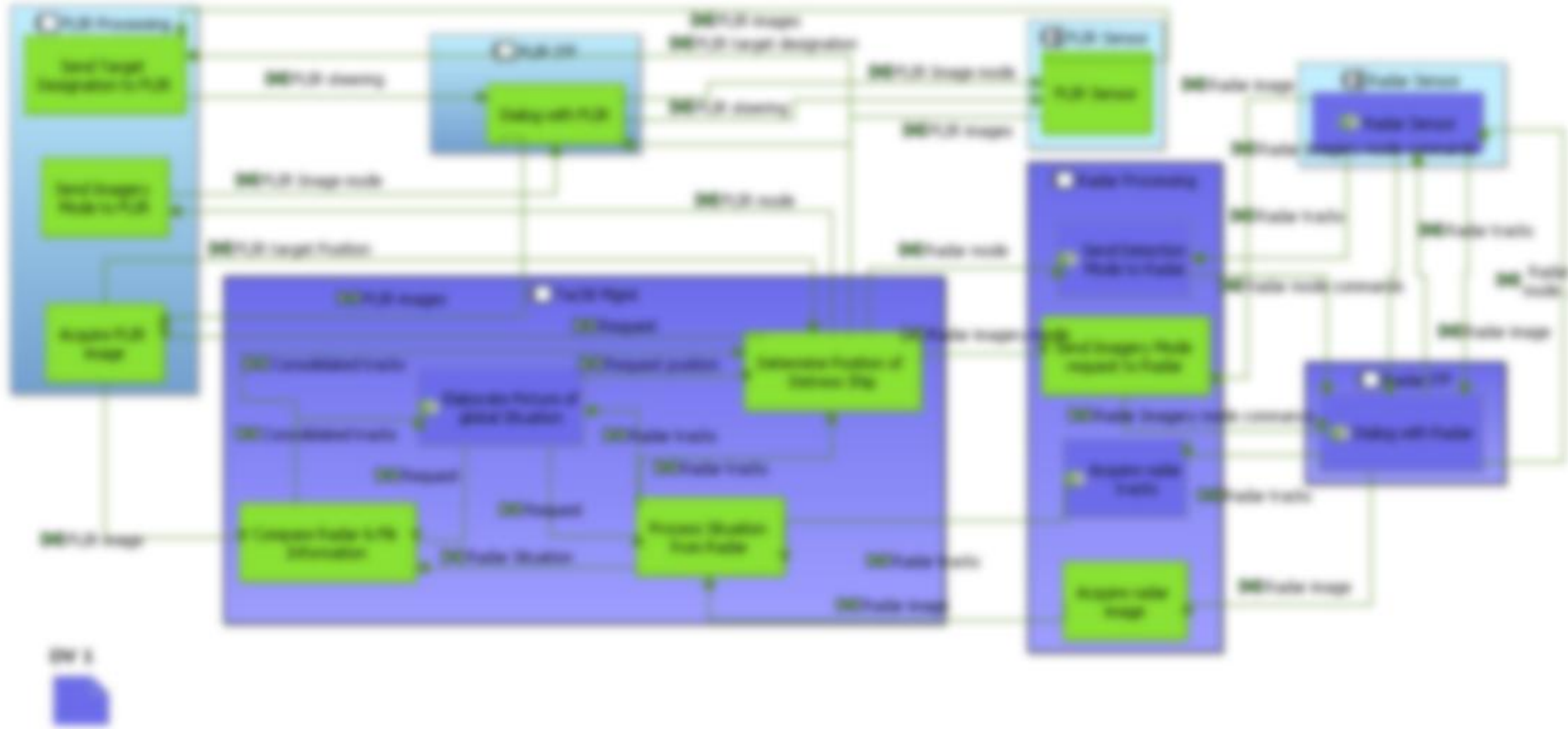
Red: Delayed, missing  
 Grey: expected in further version



**Based on an (non open source)  
 IV&V viewpoint on top of Capella**

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Developed Version 1  
 Available elements in BLUE

**Based on an (non open source) IV&V viewpoint on top of Capella**

This document  
without the pri







Developed Versions 1 & 2  
 Common available elements in GREY

**Based on an (non open source)  
 IV&V viewpoint on top of Capella**

This document  
without the pri



## Compare Planned vs Developed versions

Which expected elements are provided by this DV with ES complement ?

Version	Phase	Elements
C2 Version 5.1	Physical Architecture	
C2 Version 5.1	Physical Architecture	
C2 Version 5.1	Physical Architecture	
C2 Version 5.1	Physical Architecture	
C2 Version 5.1	Physical Architecture	
C2 Version 5.1	Physical Architecture	
C2 Version 5.1	Physical Architecture	
C2 Version 5.1	Physical Architecture	
		SEN - IFF - Create IFF Fix using IFF plot
		SEN - RAD -Control RADAR Transmission
		SEN - RAD -Edit TWS area
		SEN - IFF - Select IFF Interrogation Mode
		SEN - RAD -RADAR tracks processing
		SEN - RAD -Display RADAR video on CKD
		SEN - IFF - Delet IFF Fix
		SEN - IFF - Enter IFF search parameters in sectorial Mode
		SEN - RAD -Control RADAR frequency plan

Buttons: Clear All, Export, Display on Diagram

Based on an (non open source)  
IV&V viewpoint on top of Capella

22 / Real world examples

Capella customisations

Multi-level MBSE

Measured gains on IVV

Progress Monitoring

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23 / Real world examples

Safety: Essential Data  
Prototype

Safety Rules verification  
Prototype

Cost estimation

Legacy Interfaces

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24 / Real world examples

Code generation

Product Line modelling

Model-driven IVV

Performance analysis

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And more to come!



**Thank you for  
your attention!**  
**Any Questions?**

## Capella Open Source Project

<https://www.polarsys.org/projects/capella>

**Capella**

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**PRE-RELEASE VERSION AVAILABLE!**

The Capella Eclipse IP review process is well-engaged. In the mean time, a pre-release is available for download. Capella is a mature workbench that has been used by hundreds of architects in all Thales domains worldwide for about 5 years. It is now made available as an open source solution.

Much more than just yet another modelling tool, Capella is a model-based engineering solution that has been successfully deployed in a wide variety of industrial contexts. Based on a graphical modelling workbench, it provides systems, software and hardware architects with rich methodological guidance relying on **Arcadia**, a comprehensive model-based engineering method.

- Ensure engineering-wide collaboration by sharing the same reference architecture
- Master the complexity of systems and architectures
- Define the best optimal architectures through trade-off analysis
- Master different engineering levels and traceability with automated transition and information refinement

News

2014/10/29 **Talk** EclipseCon, Ludwigsburg, Germany

2014/10/27 **Keynote** MBSE Symposium, Canberra, Australia

2014/10/27 **Talk** MBSE Symposium, Canberra, Australia

2014/10/27 **Workshop** MBSE Symposium, Canberra, Australia

2014/10/21 **Talk** DSML, Portland, US

2014/09/14 **Keynote** Workshop ITSLE, Vasteras, Sweden

GitHub | Twitter | LinkedIn

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