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# Arcadia and Capella on the Field: Real-World MBSE Examples

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OPEN

**THALES**

## 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

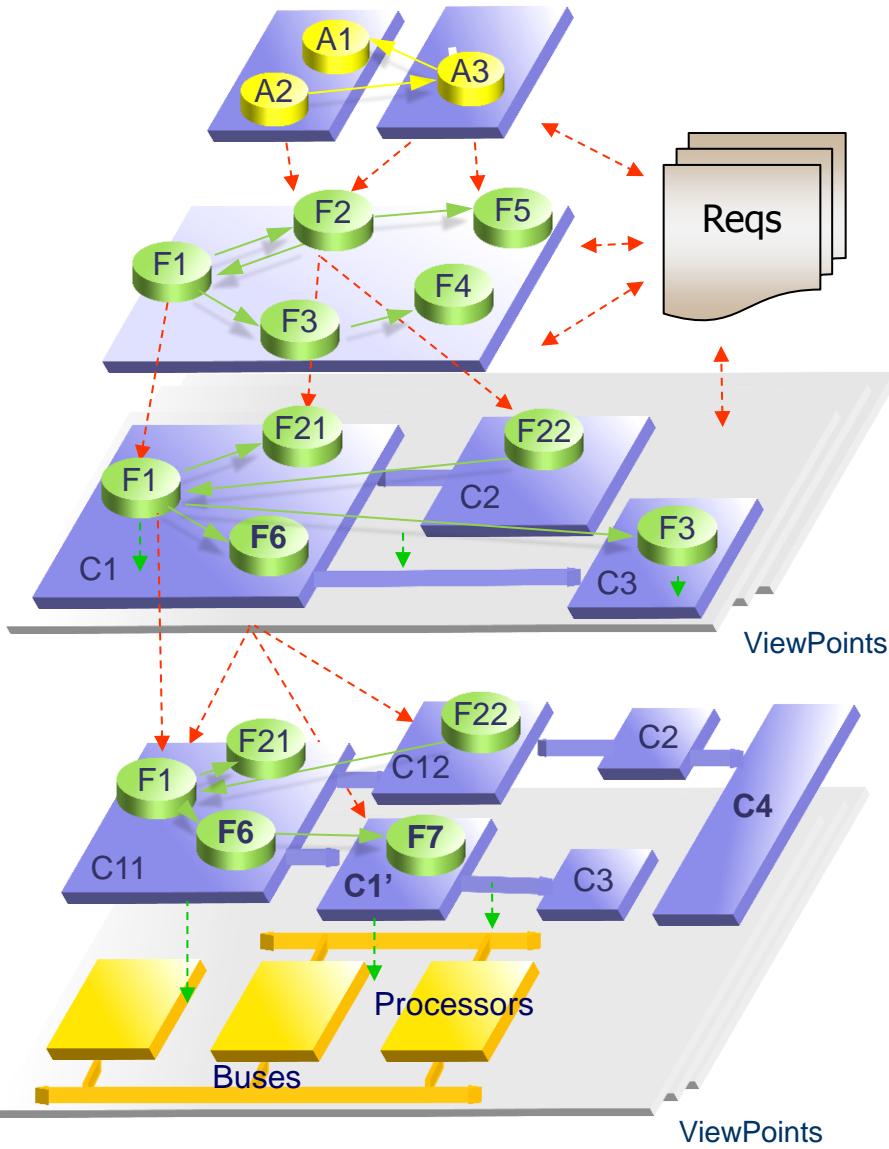
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# Arcadia: Model-Based Method for Architectural Design



NEED UNDERSTANDING

SOLUTION ARCHITECTURAL DESIGN

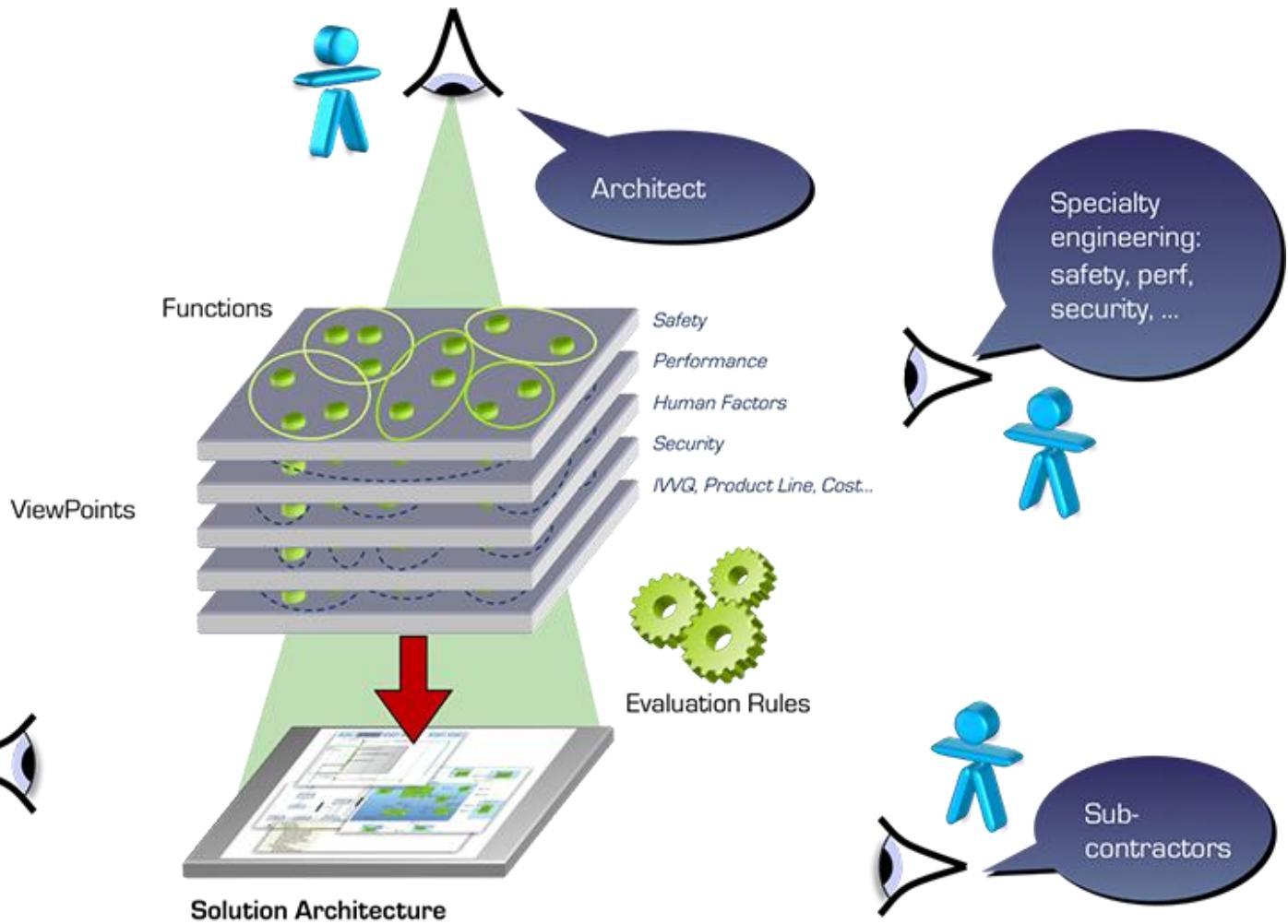


What the users of the system need to accomplish

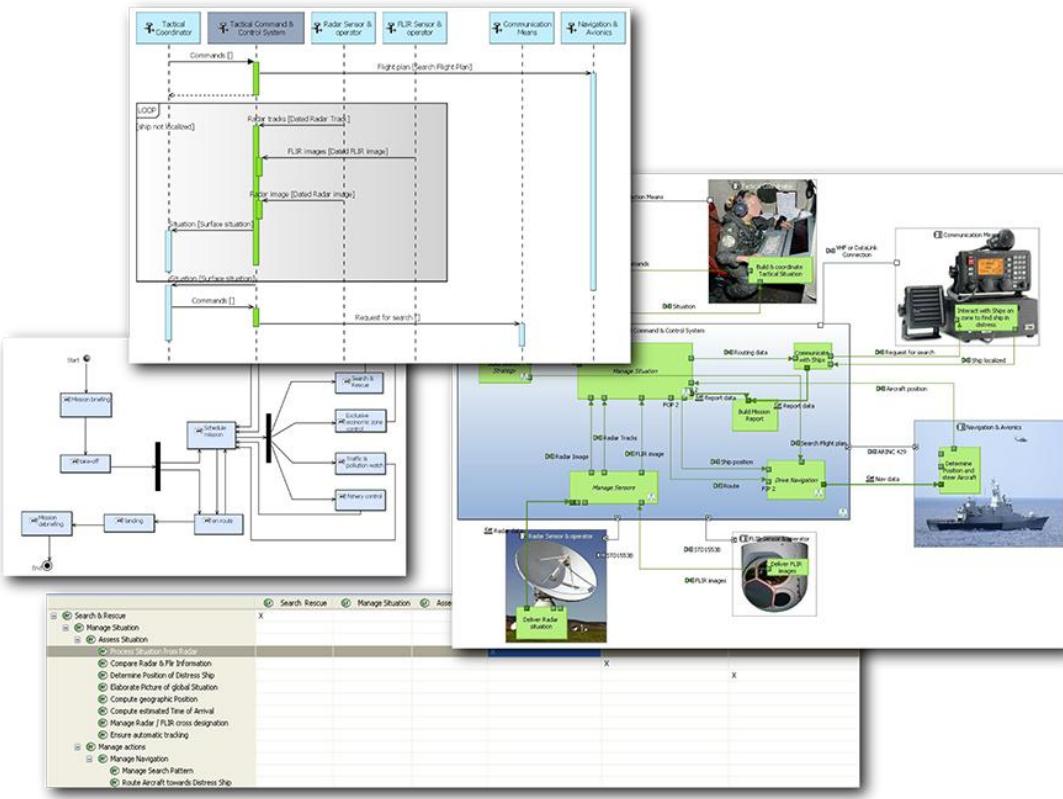
What the system has to accomplish for the users

How the system will work to fulfill expectations

How the system will be developed and built



- **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

# Capella: Embedded Methodological Guidance

**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** → 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)**

```

sequenceDiagram
    participant CC as Cabin Crew
    participant D as Doors
    participant FC as Flight Crew
    participant C as Cabin
    CC->>D: Lock command
    activate D
    D-->>CC: Lock status
    deactivate D
    CC->>C: Doors closed & Slides armed
    
```

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

```

graph TD
    subgraph "Aircraft"
        direction TB
        A1[Determine Position and steer Aircraft]
        A2[Communicate with Ships]
        A3[Route Aircraft towards Distress Ship]
        A4[Assess Situation]
        A5[Acquire radar tracks]
        A6[Acquire radar Image]
        A7[Acquire FLIR Image]
        A8[Manage Rescue Means]
        A9[Manage Situation]
        A10[Drop time bomb]
        A11[Consolidated tracks]
        A12[Search Zone]
        A13[Commands]
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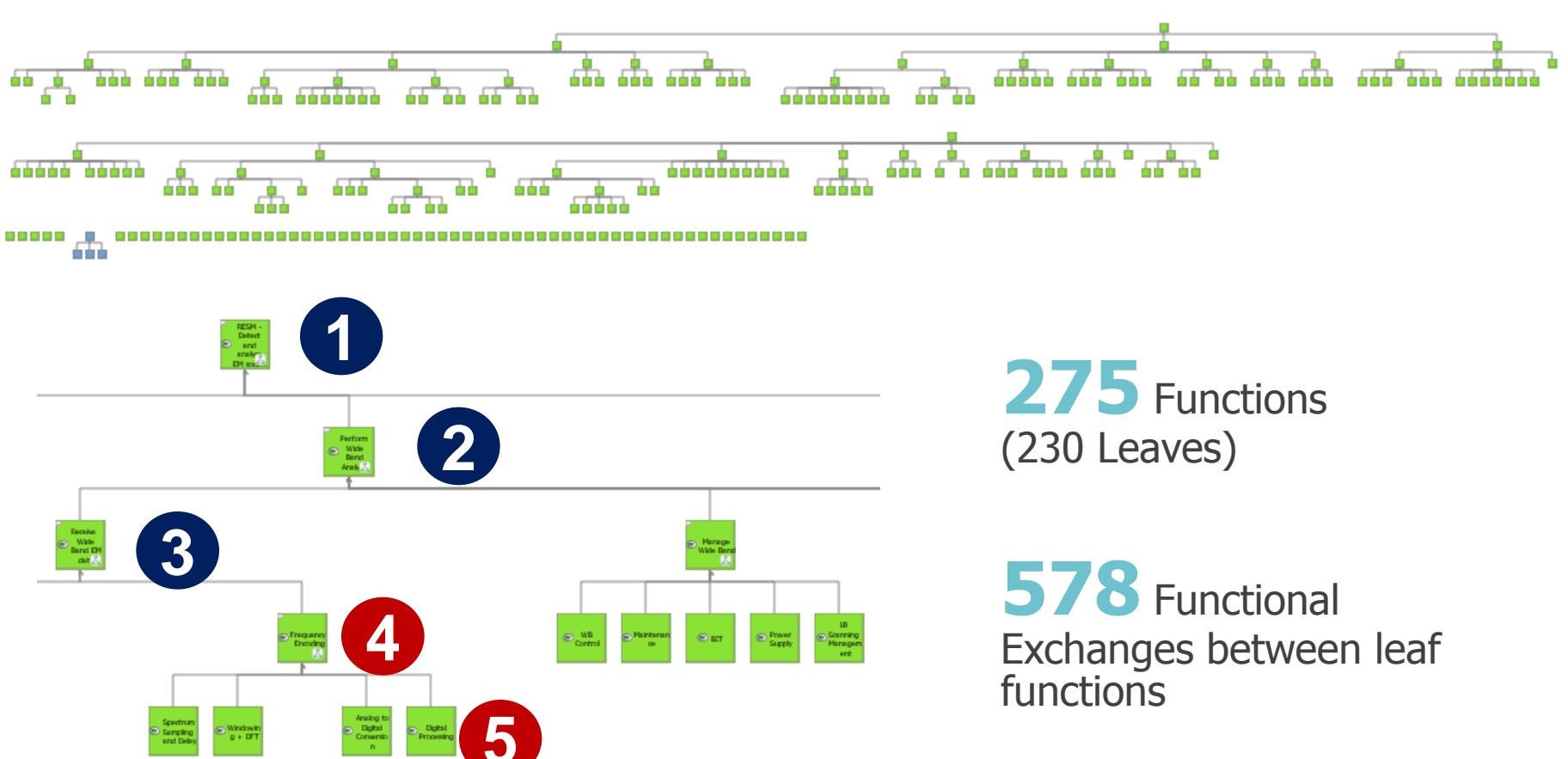
## Use Case 1: Managing System Design Complexity

## 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

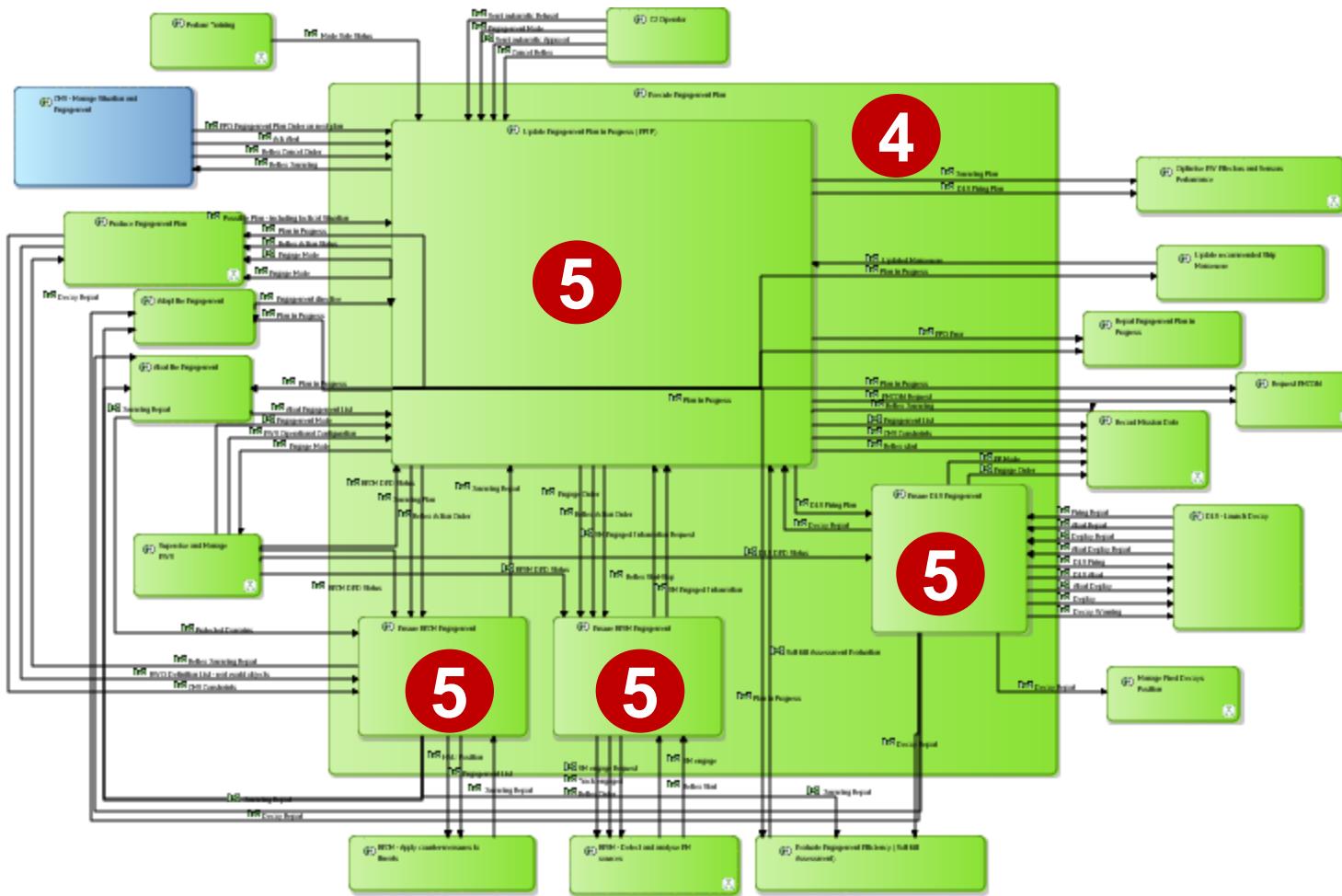


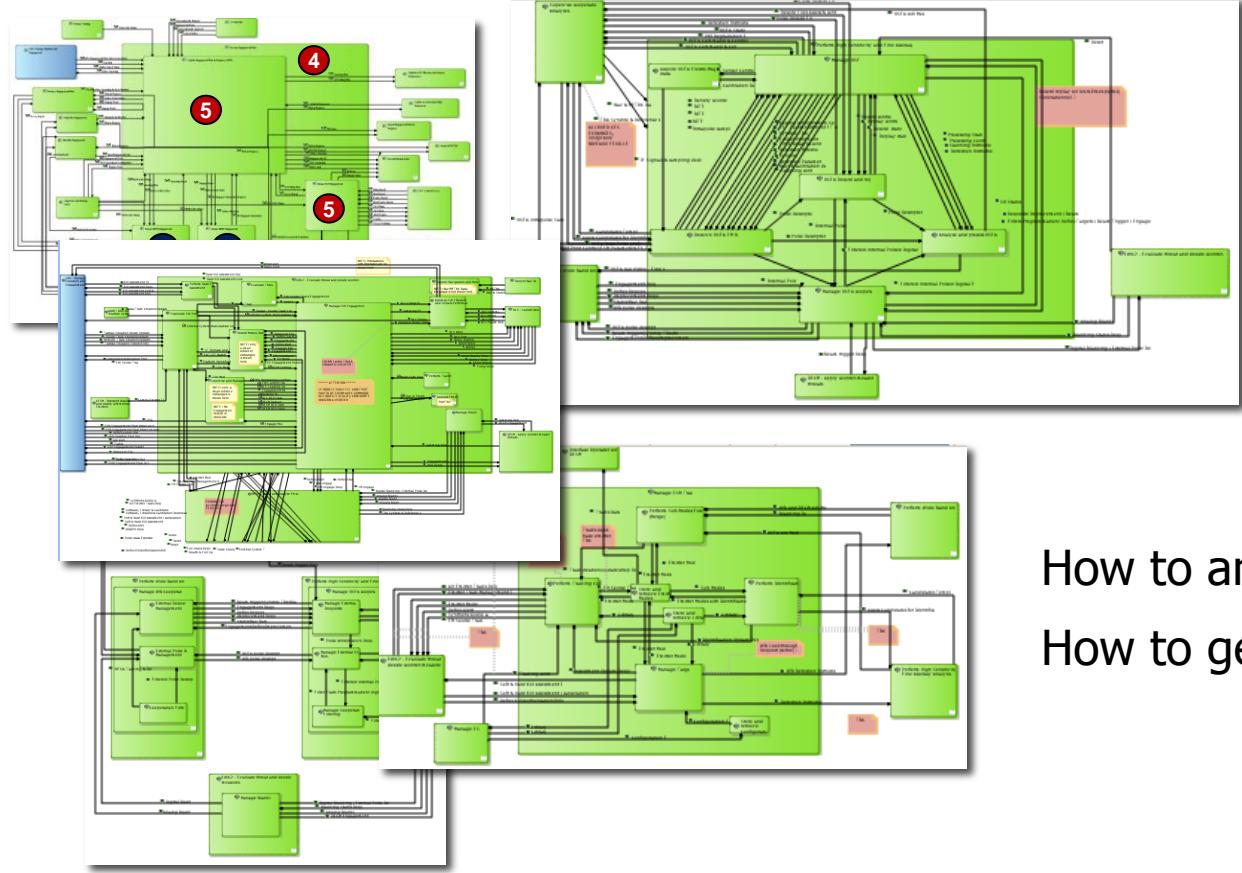
**5** levels of decomposition

third party

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## Contextual Diagrams: Low-level internals, high-level neighbourhood





X 40

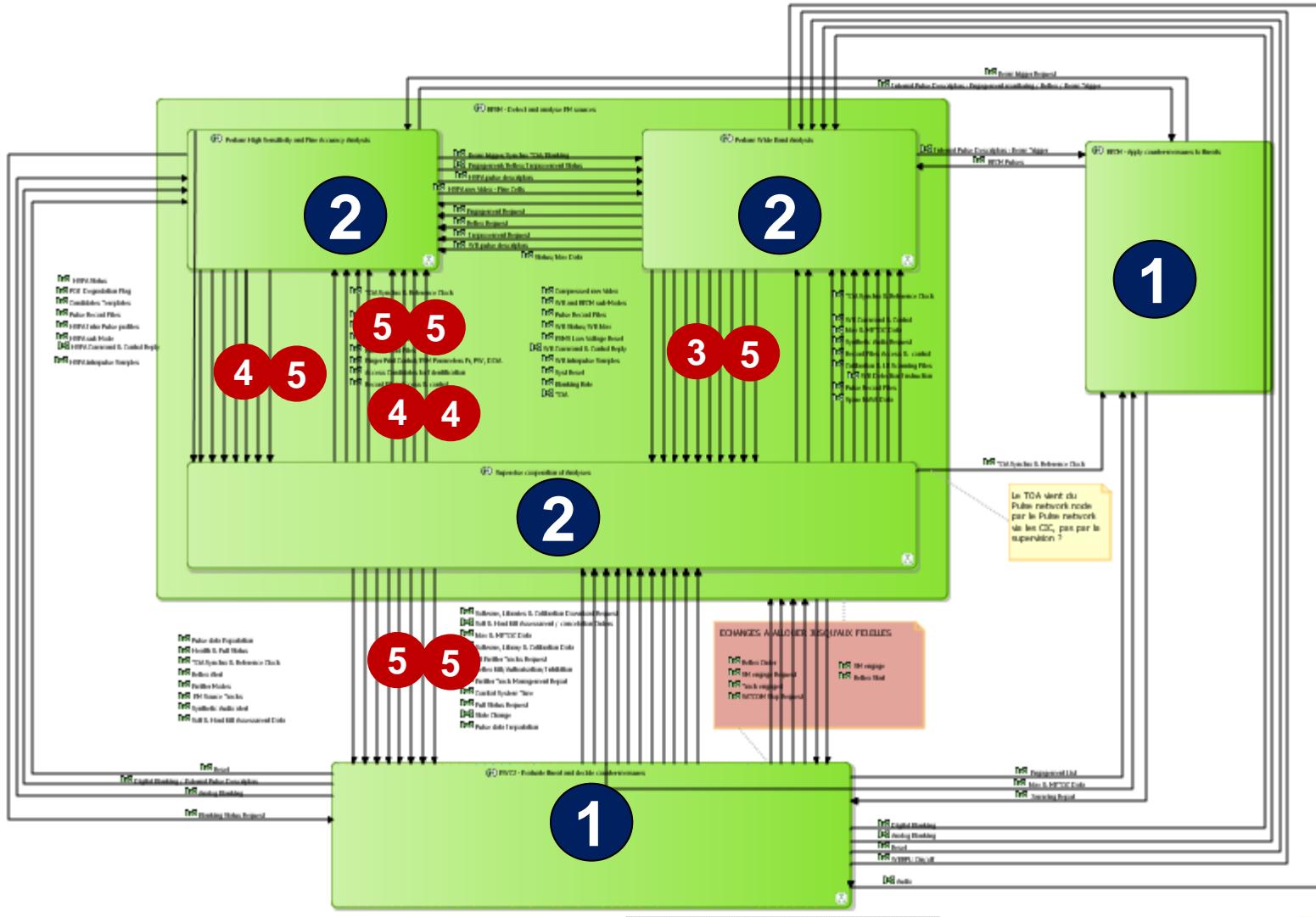
How to analyze transverse topics?  
How to get transverse overviews?

**Challenge: Build and maintain simplified views**

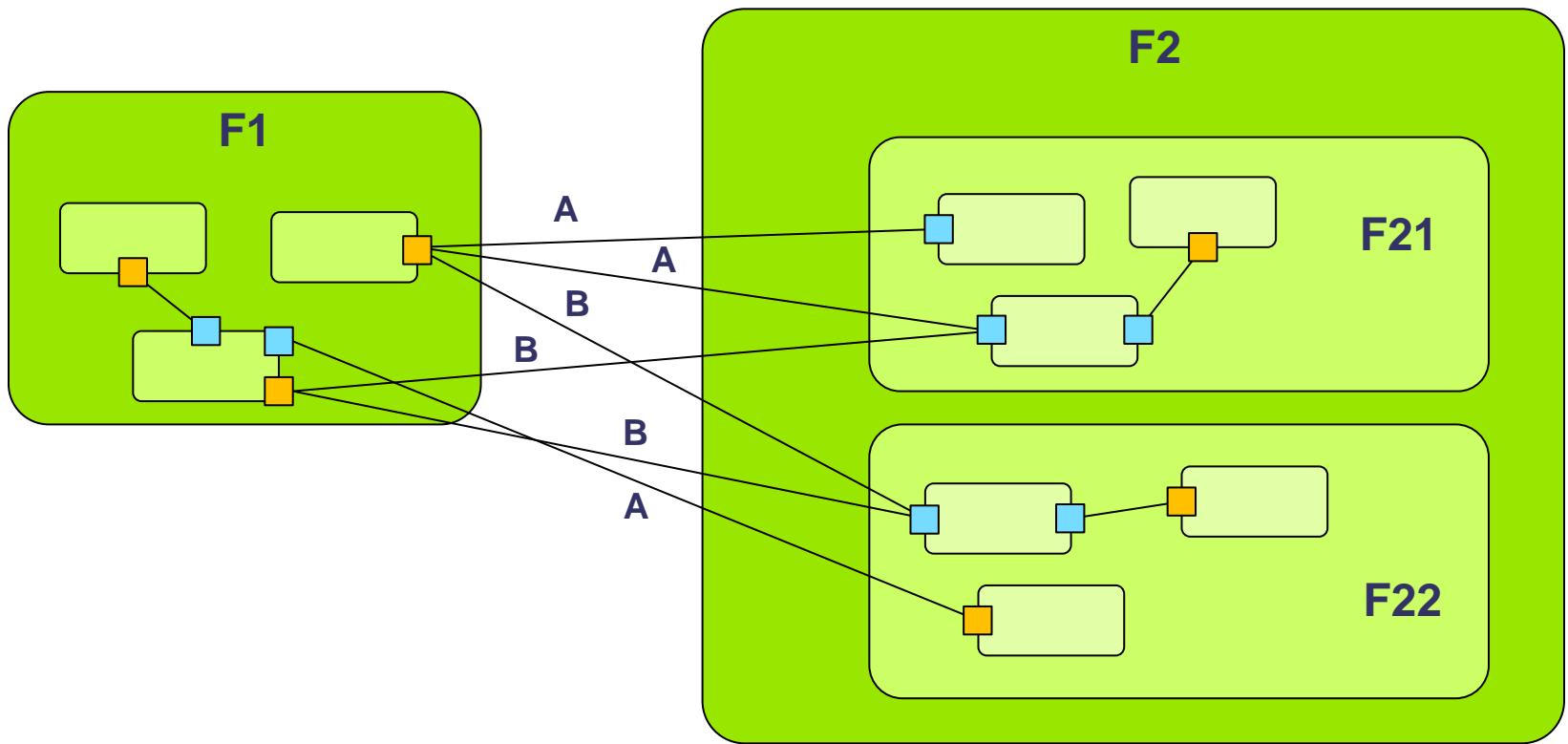
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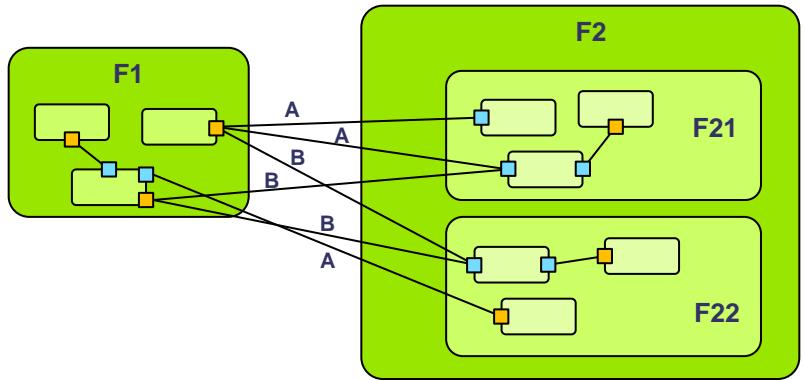
## Computed Diagrams: High-level Functions, Low-level Exchanges



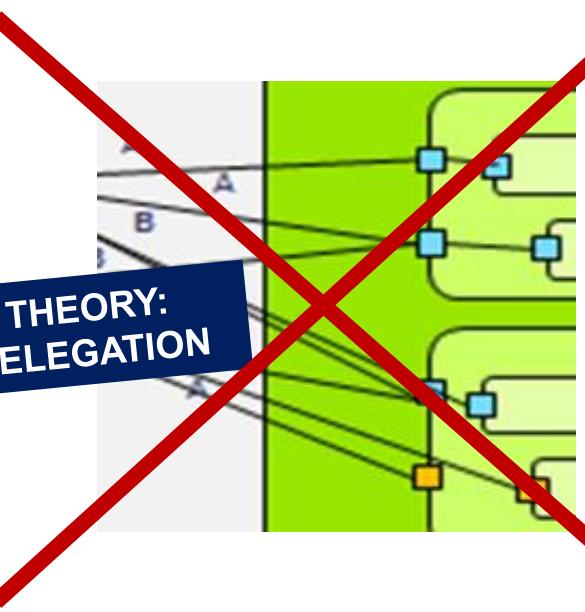
## MODEL



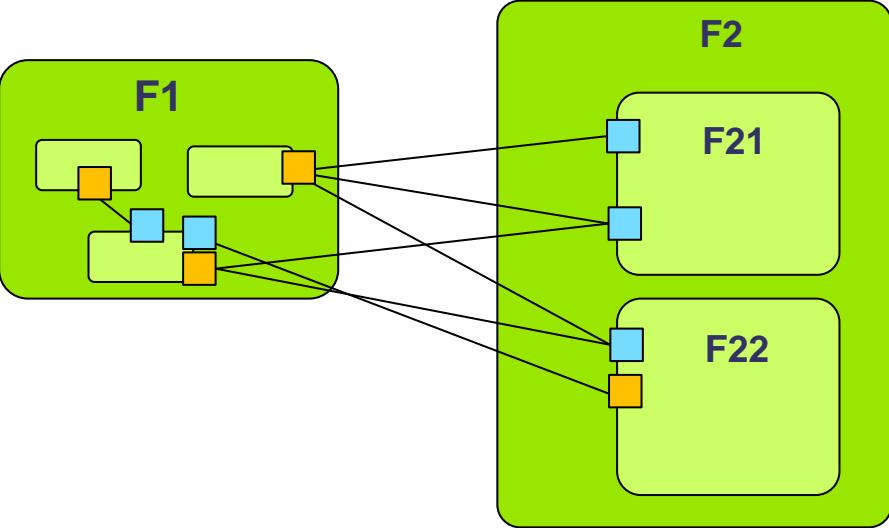
## MODEL



**THEORY:  
DELEGATION**



## VIEW



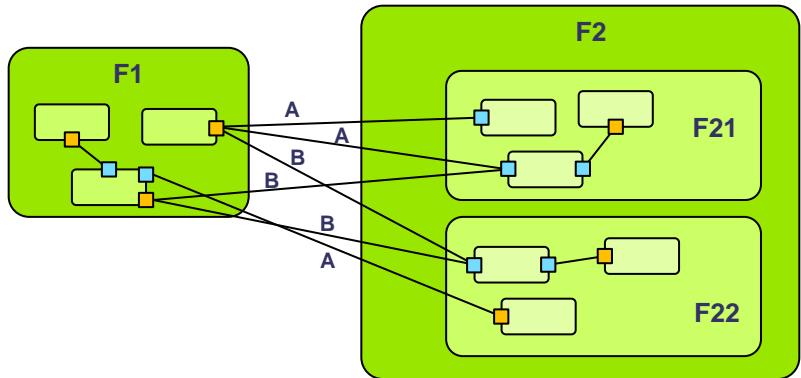
Children of F21 and F22 not displayed

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

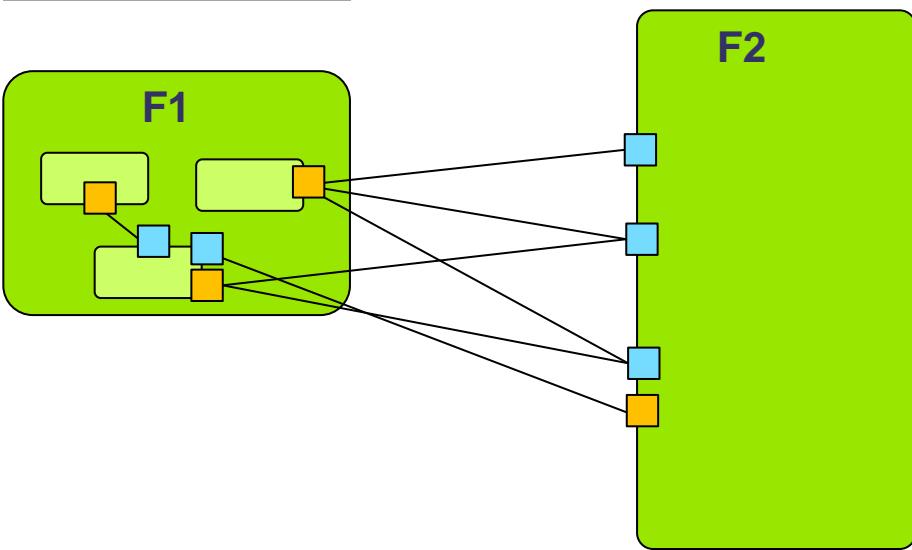
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## MODEL



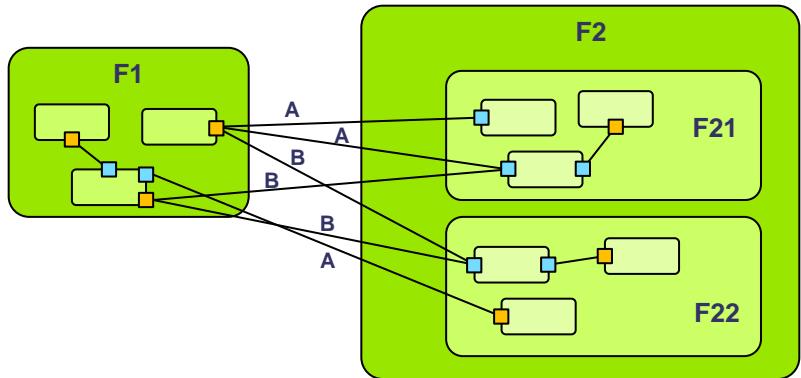
## VIEW



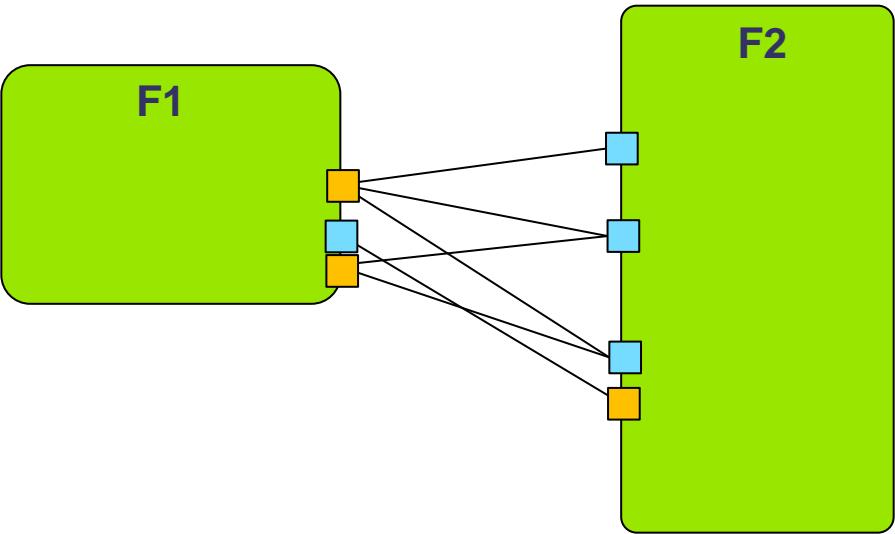
Children of F2 not displayed

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

## MODEL



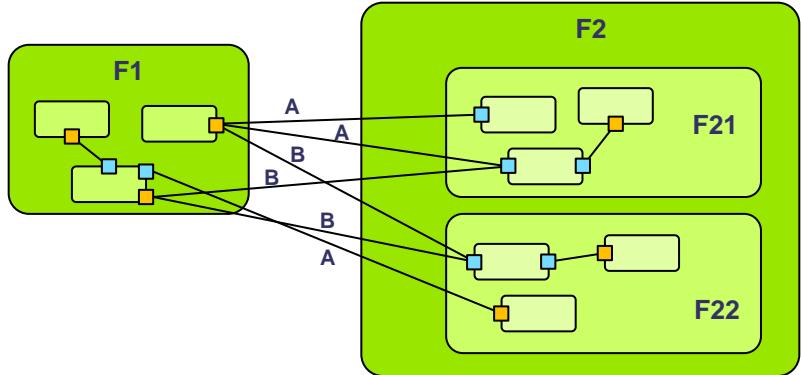
## VIEW



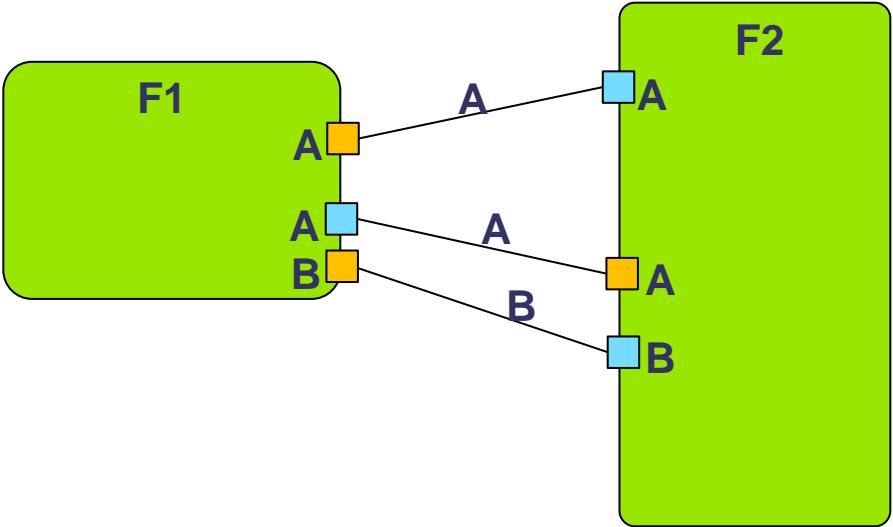
Children of F1 and F2 not displayed

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

## MODEL



## VIEW



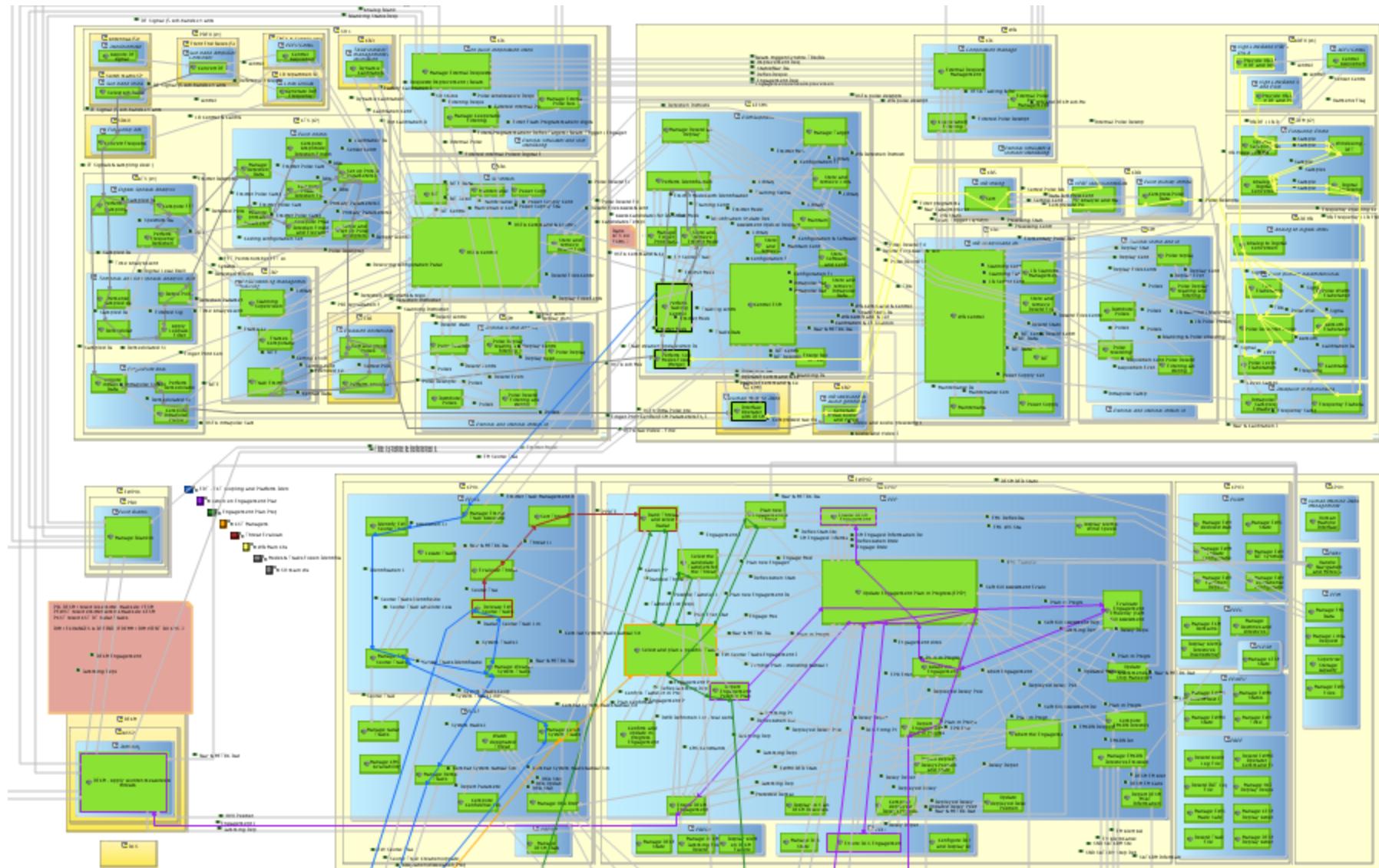
Tag-based simplification mechanism:  
each exchange can be marked with  
several « grouping » tags

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

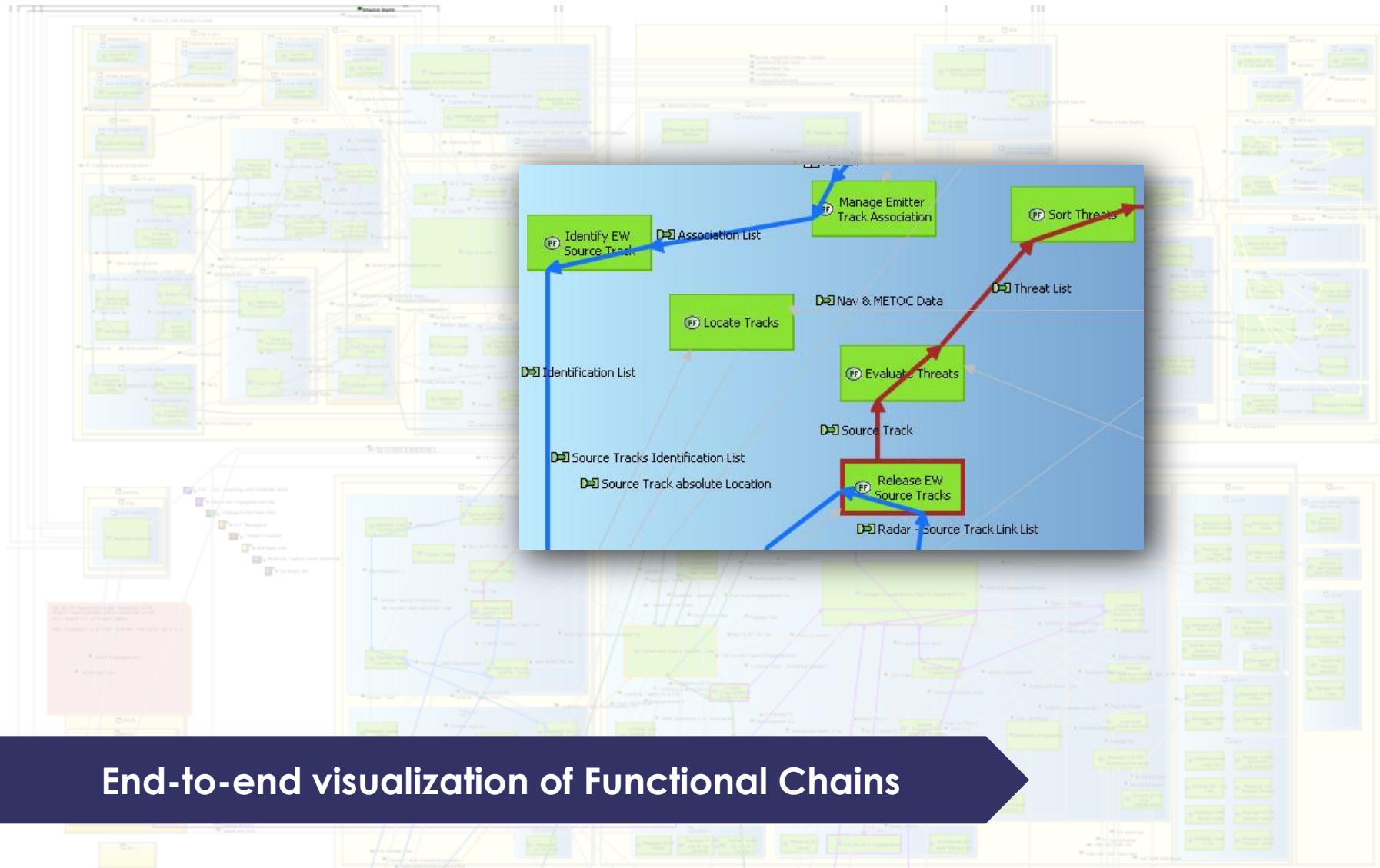
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# Managing System Design Complexity: Global Overview



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End-to-end visualization of Functional Chains

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## Use Case 2: **MBSE-based Change Management**

## Context

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

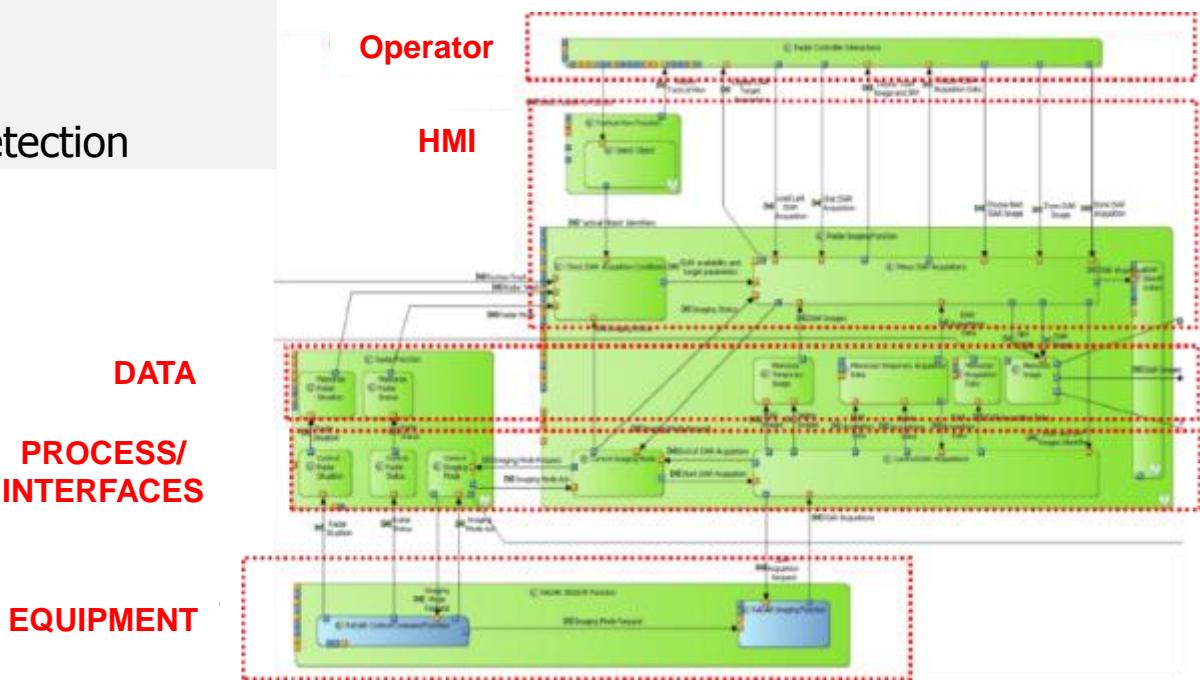
## MBSE usage

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



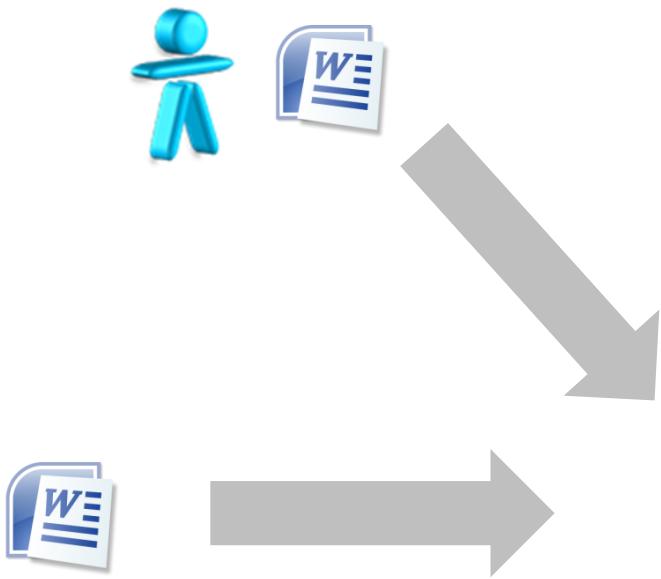
## A regular layout / reading pattern across all diagrams

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

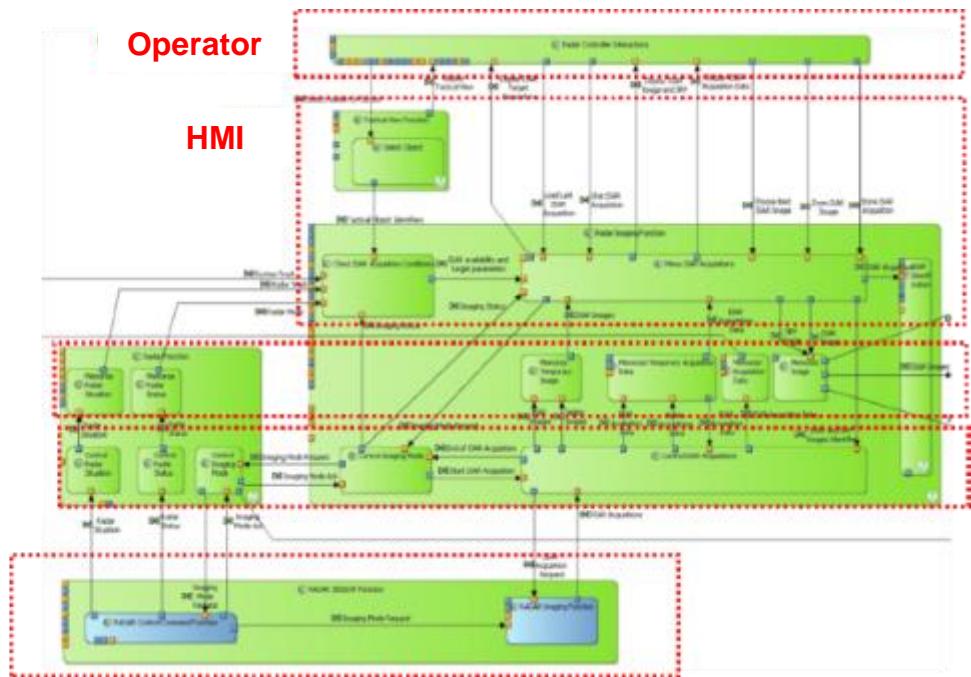


# Need Representation based on Delivered Solution

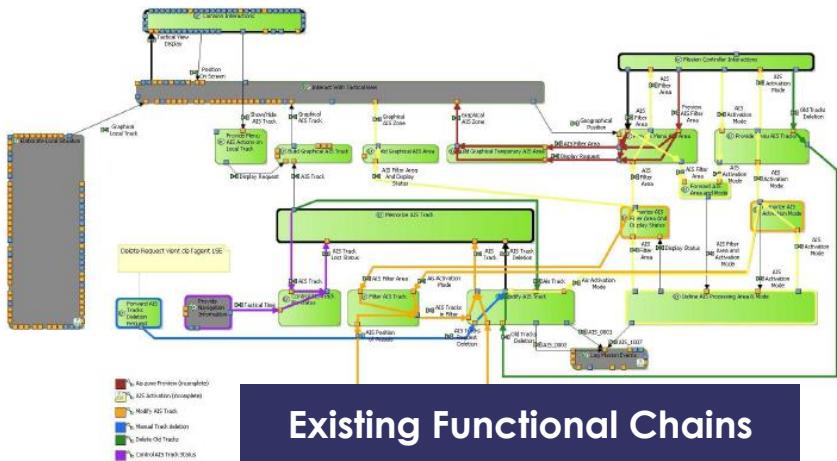
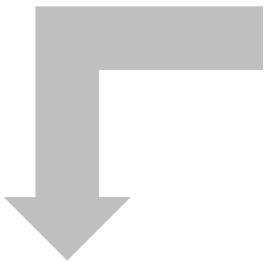
SSS: Need



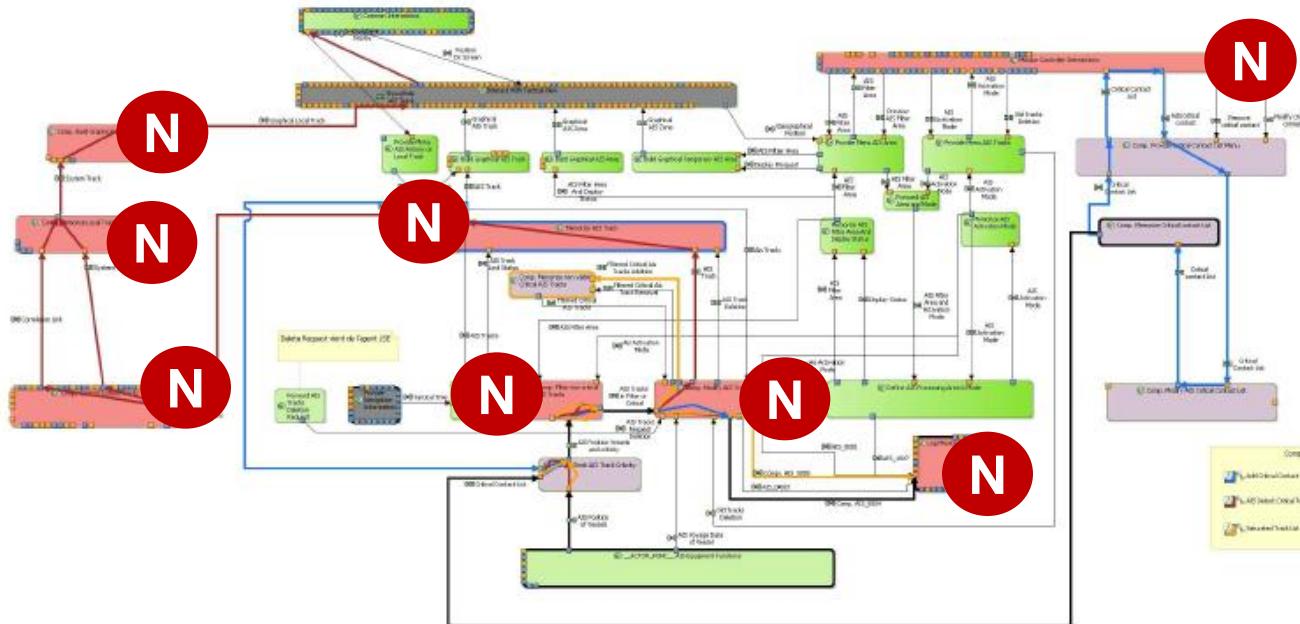
PIDS: Reverse  
Engineering from  
Software Specification



New Customer needs



Existing Functional Chains



N  
Impacted Functions



New Functional Chains

## 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

	N	O	P	Q	R	A	AI	AJ	AK	AL	AM	AP	AQ	AR
	Panneaux OM ou Interfaces internes	Interfaces externes	Memorisation : 1 si Algo: 1 si				Fonctions chiffrées			Complexité Calculée	Implémenté TU sans			
	528	1485	82	45	697		238			13650				
	800	1300	70	50	400		239			14843				
Complexité	7	2	5	2	10		1 #####							
Totaux	528	1485	82	45	697		234	238		16009	13912			
	1	3	0	0	5		1	1		69	69			
	0	3	0	0	1		1	1		20	20			
	0	4	0	1	0		1	1		18	18			
							0							
							2	1		101	101			
							0	1		32	32			
							2	1		96	96			
							2	1		70	70			
							1	1		30	30			
							0							
							1	1		57	57			
							0	1		10	10			
							0							
							0	1		14	14			
							0	1		31	31			
							2	3		20	20			
							0							
							0	6		17	17			
							0	6		17	17			
							0	8		23	23			
							4	8		103	103			
							0	5		10	10			
							0	4		10	10			

Capella Outputs  
(model export)



## Use Case 3: Multi-Level Engineering

OPEN

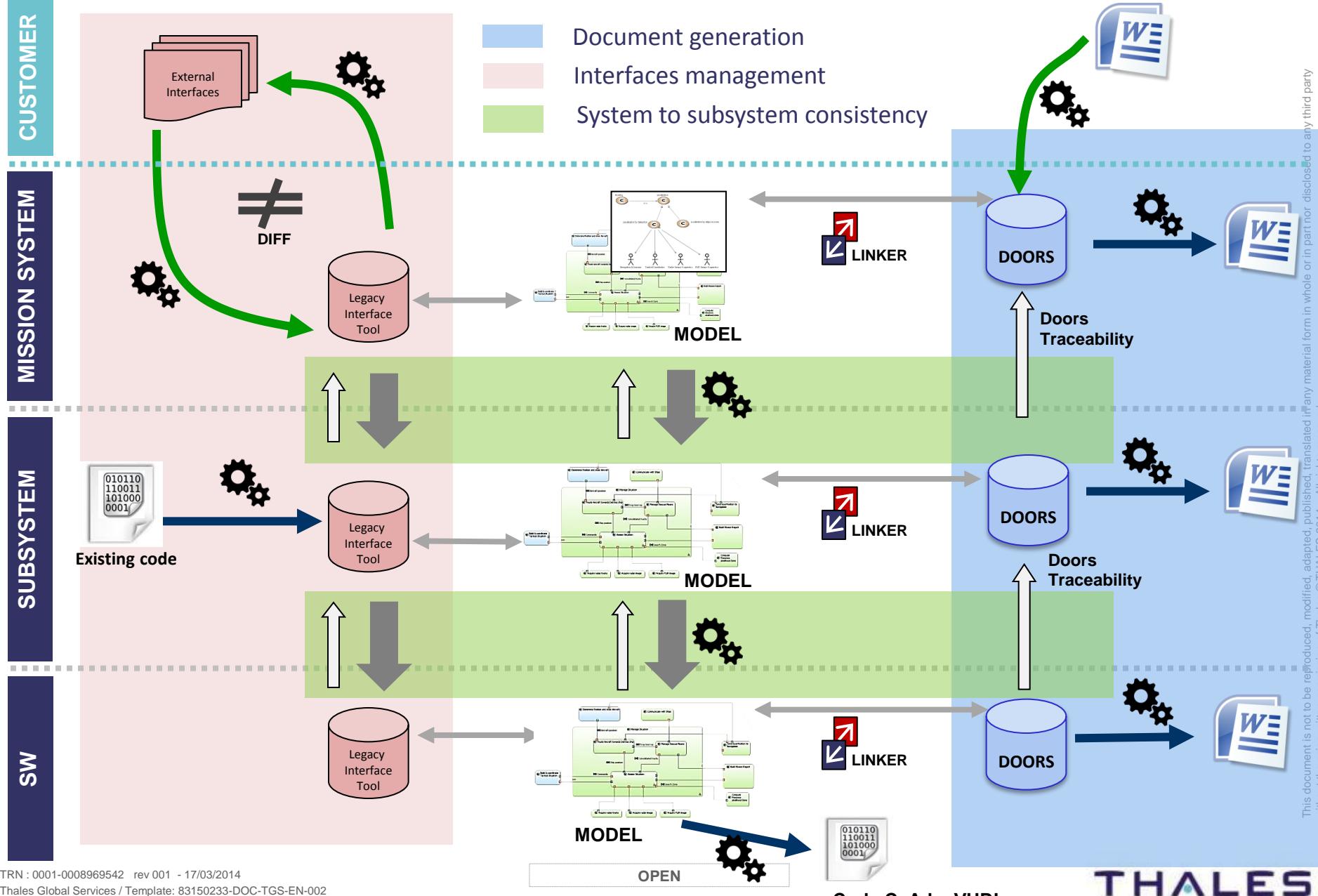
**THALES**

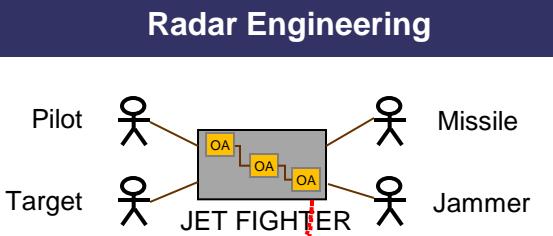
## Context



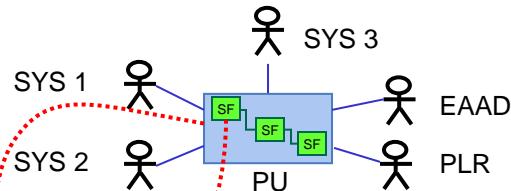
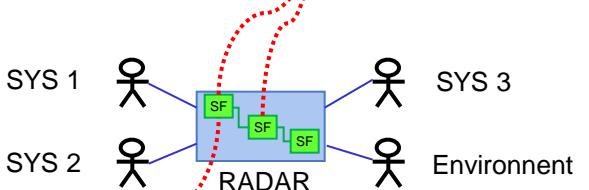
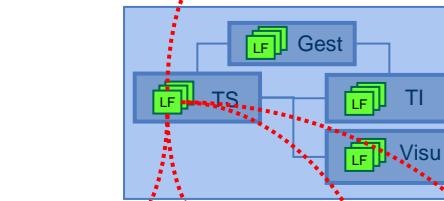
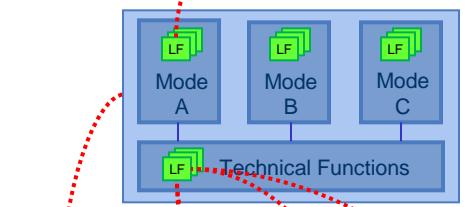
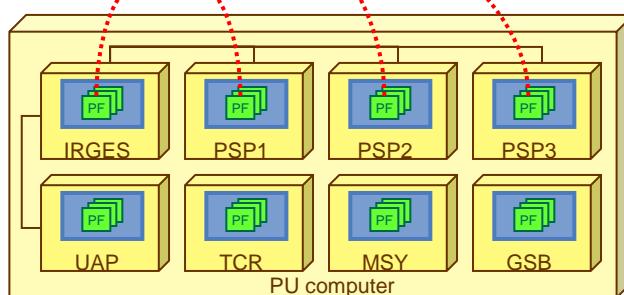
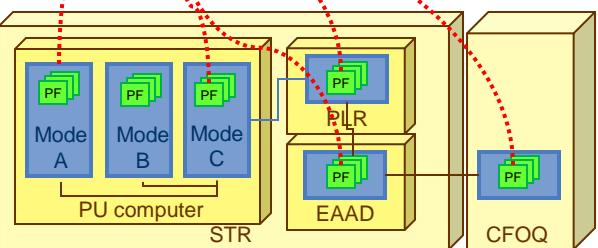
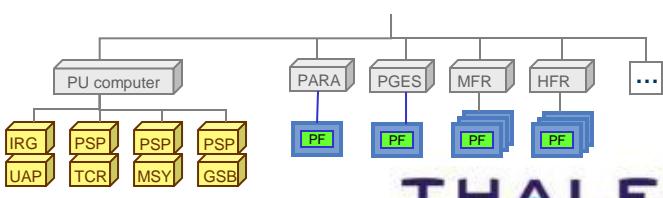
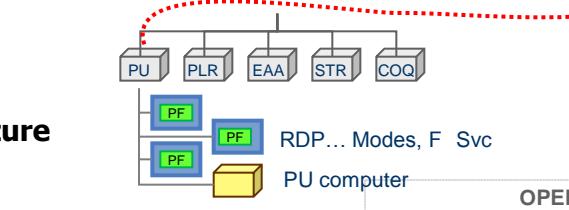
## MBSE usage

- 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



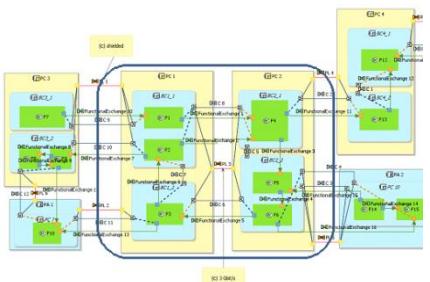
**Operational Analysis****Processing Unit Engineering**

Traceability link

**System Analysis****Logical Architecture****Physical Architecture****Product Breakdown Structure**

**THALES**

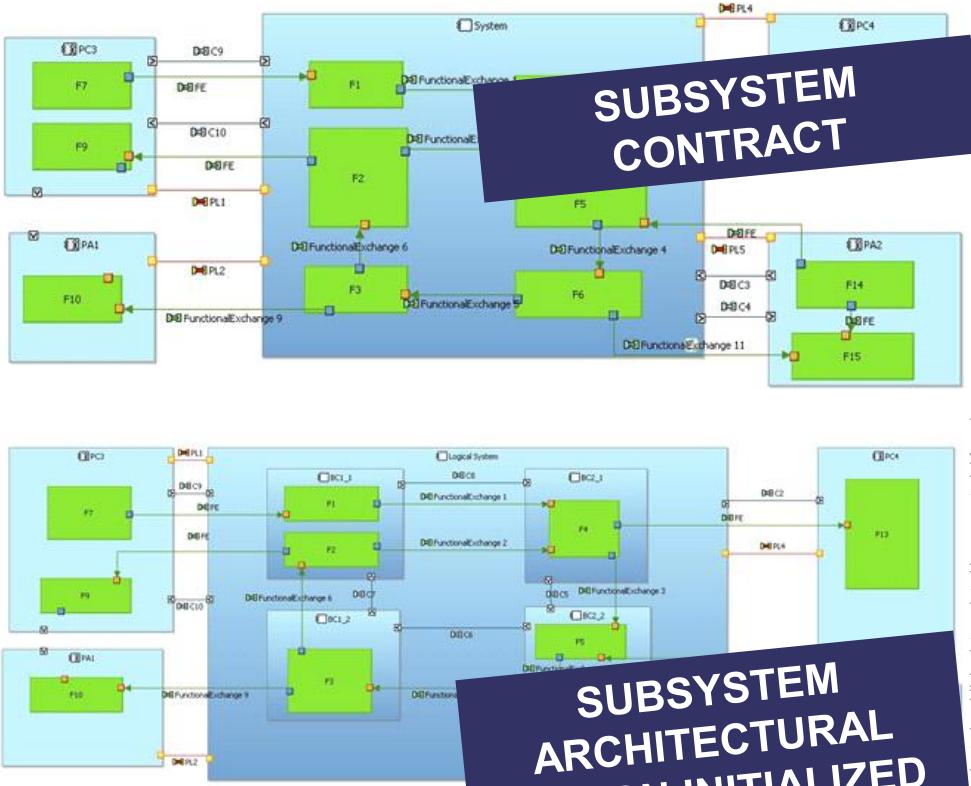
## System Physical Architecture



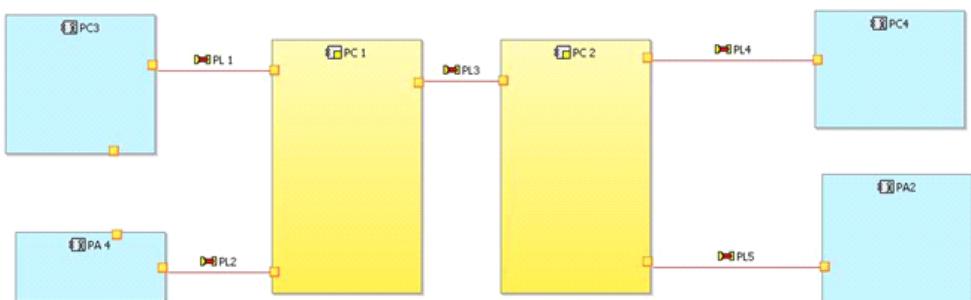
## Subsystem Need Analysis

**CO-ENGINEERING**

## Subsystem Logical Architecture

**SUBSYSTEM CONTRACT**

## Subsystem Physical Architecture

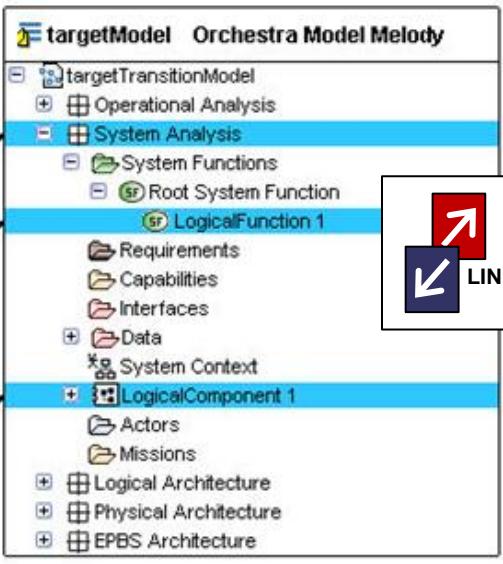
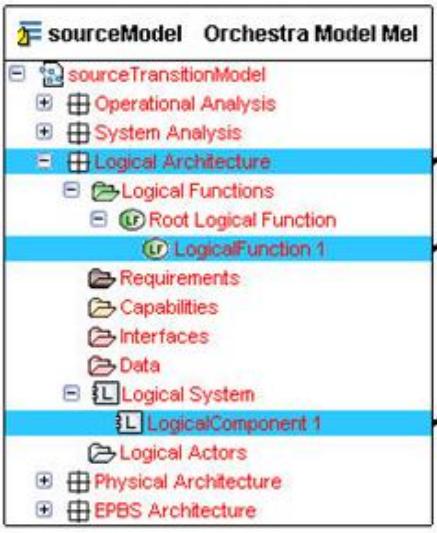
**SUBSYSTEM ARCHITECTURAL DESIGN INITIALIZED**

OPEN

**THALES**

System Physical Architecture

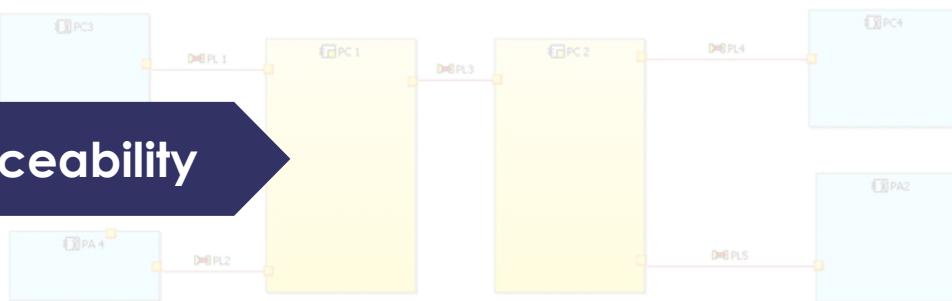
Subsystem Need Analysis



CO-EN

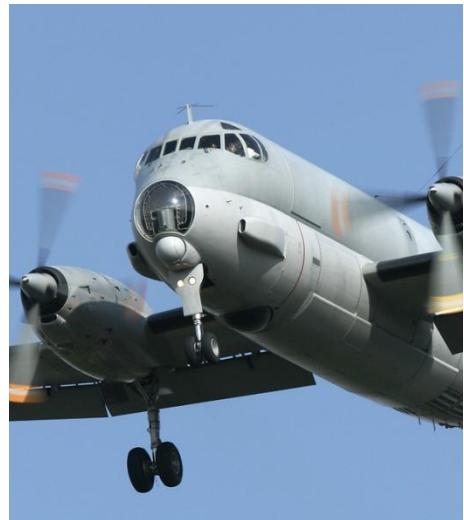
**SUBSYSTEM CONTRACT****SUBSYSTEM ARCHITECTURAL DESIGN INITIALIZED**

Subsystem Physical Architecture

**Computed system - subsystem traceability**

OPEN

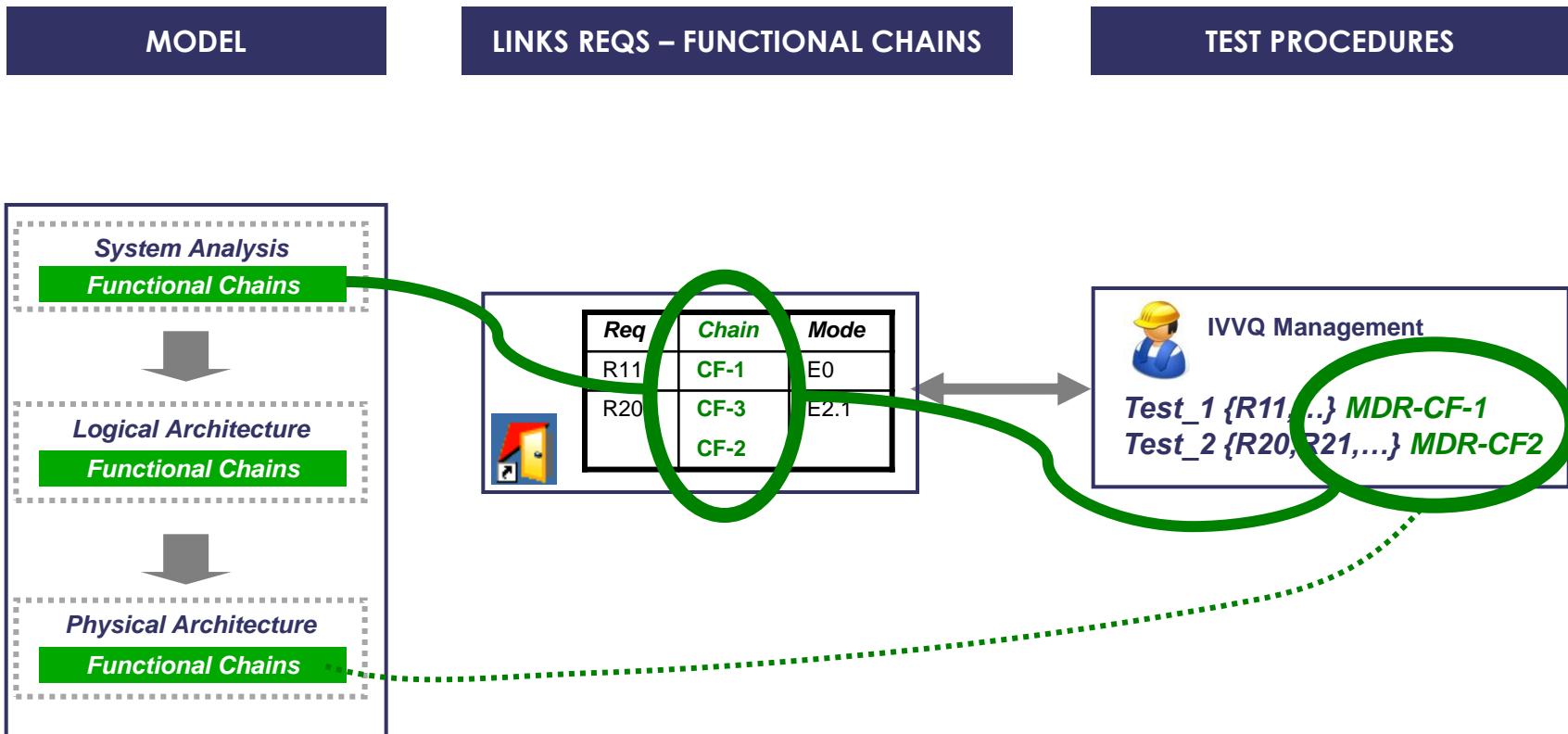
**THALES**



## 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

Version

- REQUESTED
  - Mission System Standards
    - Standard 1 - SEN-RAD + SEN-IPF + SEN-AIS + SEN-FLIR basic
    - Standard 2 - SEN-RAD + SEN-IPF + SEN-AIS + SEN-FLIR + EWS-ESM Basic
    - Standard 3 - SEN-RAD + SEN-IPF + SEN-AIS + SEN-FLIR + EWS-ESM + EWS-SPS
- DEVELOPED
  - TEST
  - Other
- CR DIAGNOSED
- CR CORRECTIVE
- TEST

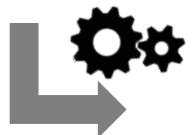
Filters

Select a name to find  
? = any character, \* = any string  
type filter text

Elements

- AMASOS
  - AMASOS
    - System Functions
      - SEN - IPF - Create IFF File using IFF plot
      - SEN - IPF - Enter IFF search parameters in sectorial Mode
      - SEN - IPF - IFF RF Management
      - SEN - IPF - IFF State Control
      - SEN - RAD - Select IFF Frequency Mode
      - SEN - RAD - Control Local Antenna
      - SEN - RAD - Control PAFAR frequency plan
      - SEN - RAD - Control Radar mode
      - SEN - RAD - Control Radar Transmission
      - SEN - RAD - Display Radar tracks using Manual Radar Track
      - SEN - RAD - Display RADAR Image on ODIS
      - SEN - RAD - Display RADAR video
      - SEN - RAD - Display RADAR video on ODIS
      - SEN - RAD - EDS TWS area
      - SEN - RAD - RADAR tracks processing

Define operational content expected for each project milestone



Version

- REQUESTED
- DEVELOPED
  - Tactical C2 Integration Versions
  - Mission System Versions
  - Flight Management System Versions
  - Inertial Navigation System
  - AIRCRAFT
  - FLIR Equipment Versions
  - MDLR Versions
  - TEST
  - Other
- Standard 0 - Expected Deliveries
- CR DIAGNOSED
- CR CORRECTIVE
- TEST

Filters

Select a name to find  
? = any character, \* = any string  
type filter text

Elements

- Physical System
  - Manage SITAC
    - Modify rotation
    - Modify Tilt Direction
    - Receive radar signal
    - select detection mode
    - select extraction mode
  - Manage SITAC
    - Display Video on CKD Display
    - manage CKD video displaying
    - Manage correlation system tracks with radar tracks
    - manage radar video display
    - manage system tracks
  - Receive IFF signal
  - Receive RADAR signal
  - Receive video signal
  - Send RADAR Image to CKD
- AIRCRAFT
- AIRCRAFT interfaces

Deduce functional content and components to be delivered

Select a name to find  
? = any character, \* = any string  
type filter text

Elements

- Tactical C2 Integration Versions
  - C2 Version 5.1
  - C2 Version 5.2
  - C2 Version 6.1
  - C2 Version 6.2
- C2 Components
  - NAV Component Versions
    - PIC NAV 15.1
  - Tactical Situation Versions
    - PIC LSE 17.1
    - PIC LSE 17.2
  - RADAR Component Versions
    - PIC RAD 16.1
    - PIC RAD 16.2
  - Video Component Versions
    - PIC VID 19.1
    - PIC VID 19.2
- AMASOS
  - AMASOS
    - Physical Architecture
      - Physical Functions
        - Root Physical Function
        - Manage SITAC
          - Manage correlation system tracks with radar tracks
          - manage system tracks
      - Physical System
        - PIC LSE
        - TCS

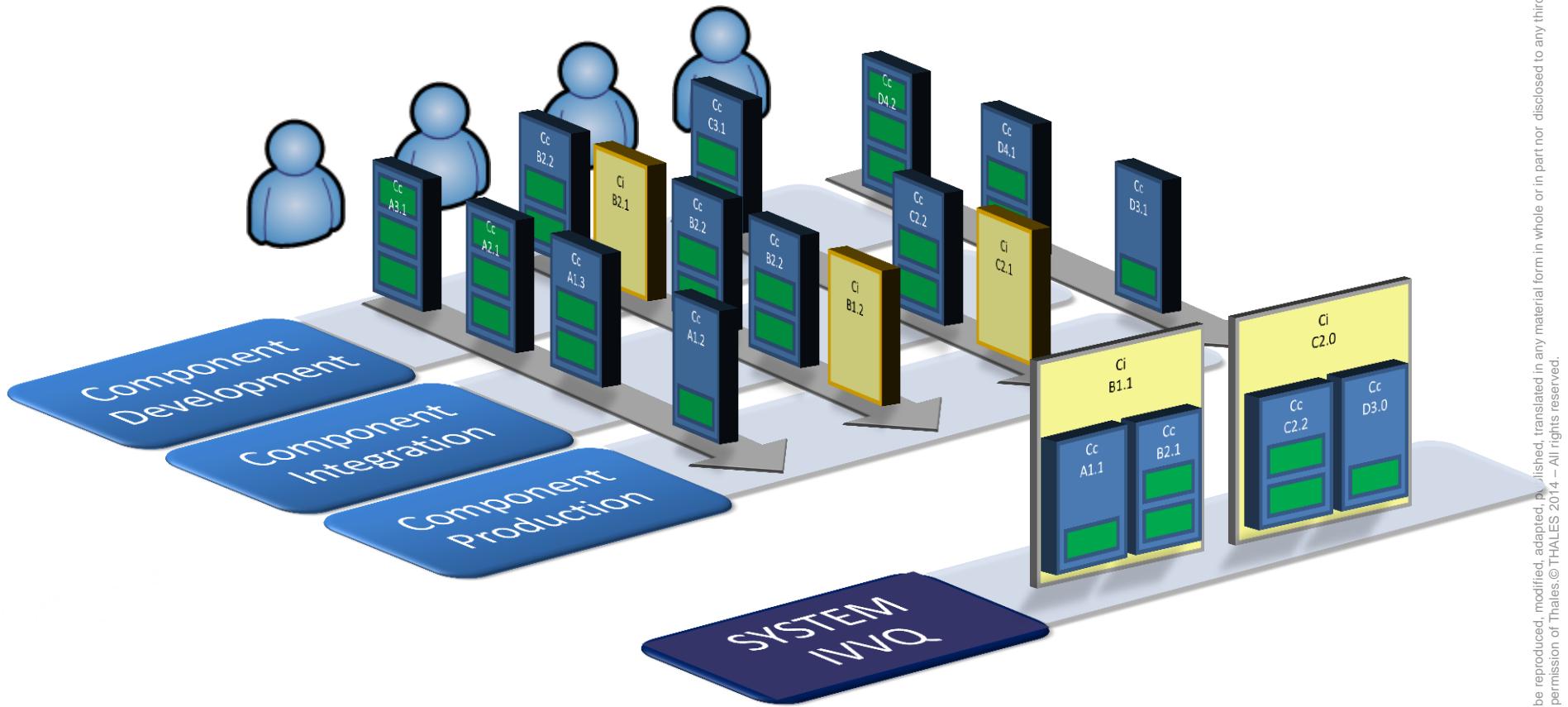
Define components versions and content

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

OPEN

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Blue: Software  
Yellow: hardware

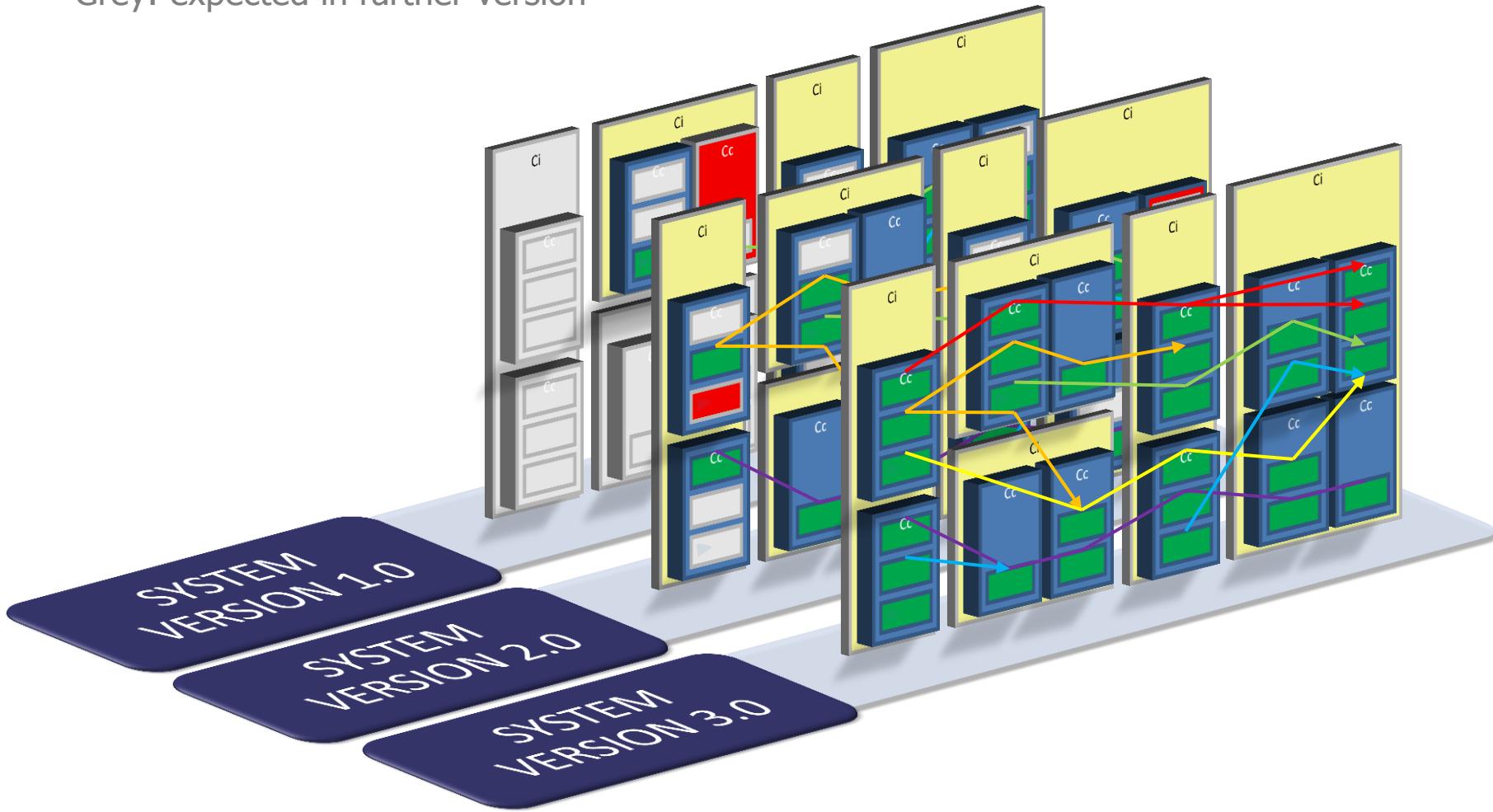


**Based on an (non open source)  
IV&V viewpoint on top of Capella**

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Red: Delayed, missing

Grey: expected in further version



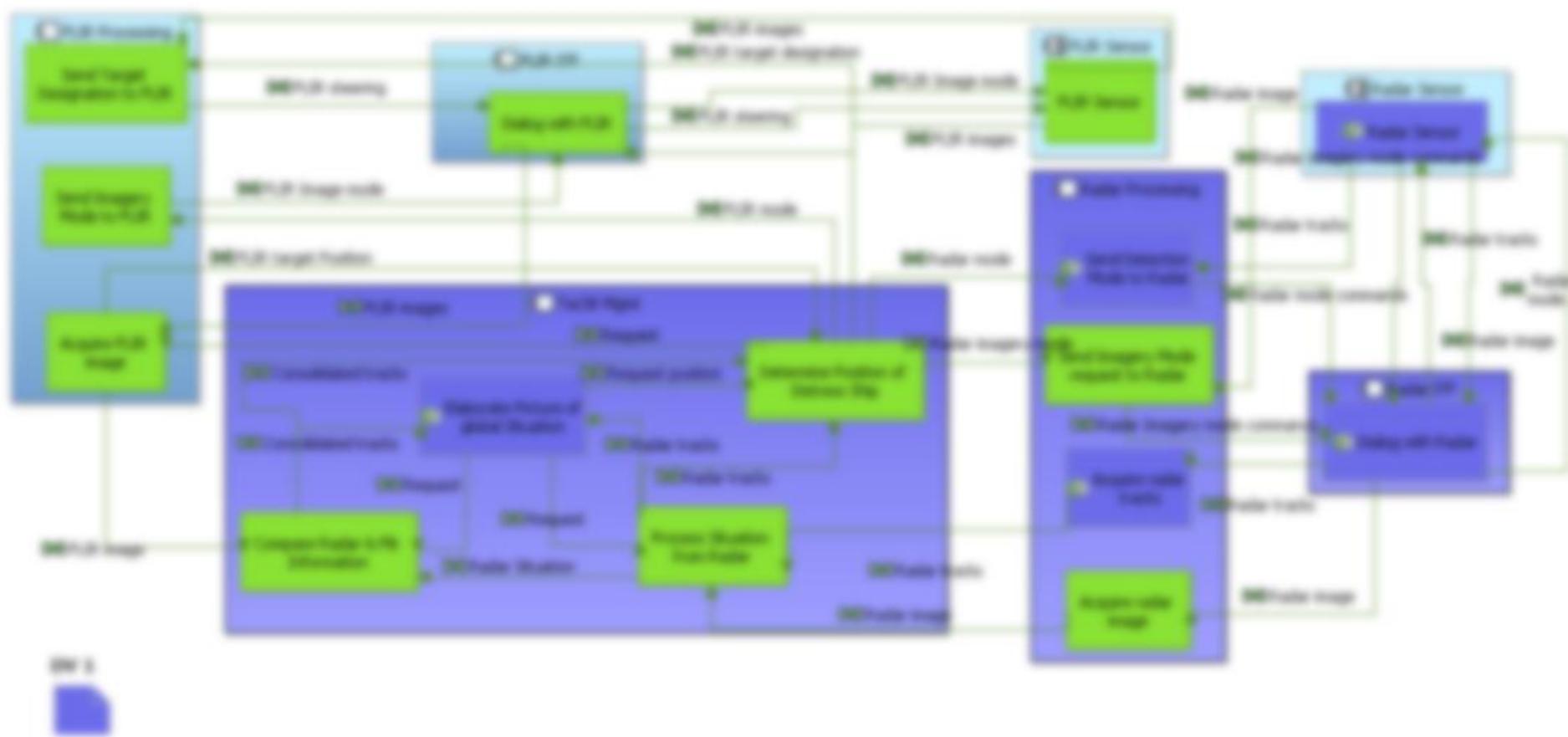
**Based on an (non open source)  
IV&V viewpoint on top of Capella**

OPEN



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

Release management viewpoint:  
Automated visualization of versions  
based on activation of diagram layers

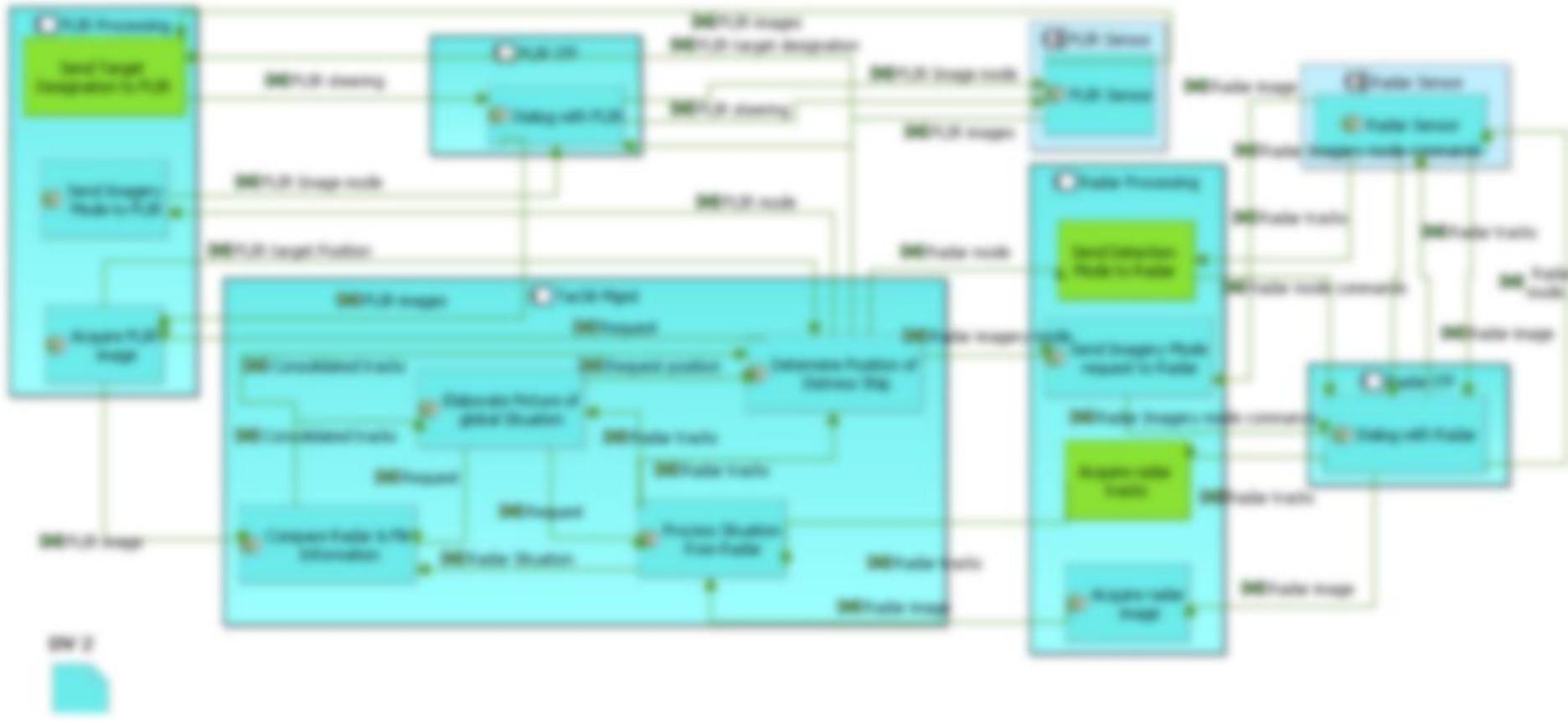


Developed Version 1  
Available elements in BLUE

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

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# Developed Version 2

## Available elements in CYAN

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

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# Developed Versions 1 & 2

## Common available elements in GREY

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

TRN : 0001-0008969542 rev 001 - 17/03/2014

Thales Global Services / Template: 83150233-DOC-TGS-EN-002

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## Compare Planned vs Developed versions

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### Real world examples

**Capella customisations**

**Multi-level MBSE**

**Measured gains on IIV**

**Progress Monitoring**

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### Real world examples

**Safety: Essential Data Prototype**

**Safety Rules verification Prototype**

**Cost estimation**

**Legacy Interfaces**

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### Real world examples

**Code generation**

**Product Line modelling**

**Model-driven IIV**

**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>

The screenshot shows the Capella website homepage. At the top, there is a navigation bar with links to HOME, ARCADIA, FEATURES, GETTING STARTED, EVENTS, and COMMUNITY. A 'Download' button is located on the right side of the navigation bar. Below the navigation bar, there is a section titled 'PRE-RELEASE VERSION AVAILABLE!' which contains text about the pre-release version and its availability. To the right of this section is a 'News' sidebar listing several events and talks from 2014. At the bottom right of the page, there is a logo for 'eclipse incubation' and social media icons for Twitter and LinkedIn.

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