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Arcadia and Capella on the Field: Real-World MBSE Use Cases

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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

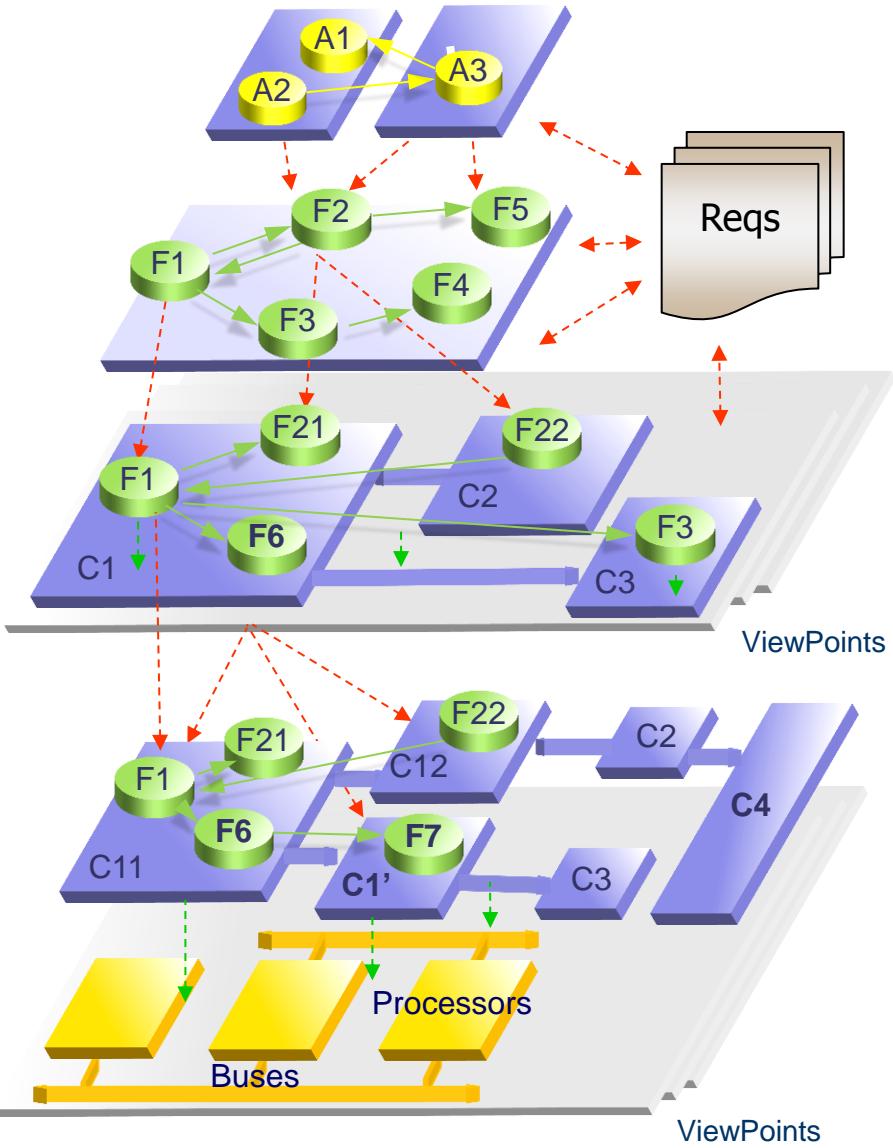
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Arcadia: Model-Based Method for Architectural Design



NEED UNDERSTANDING

SOLUTION ARCHITECTURAL DESIGN

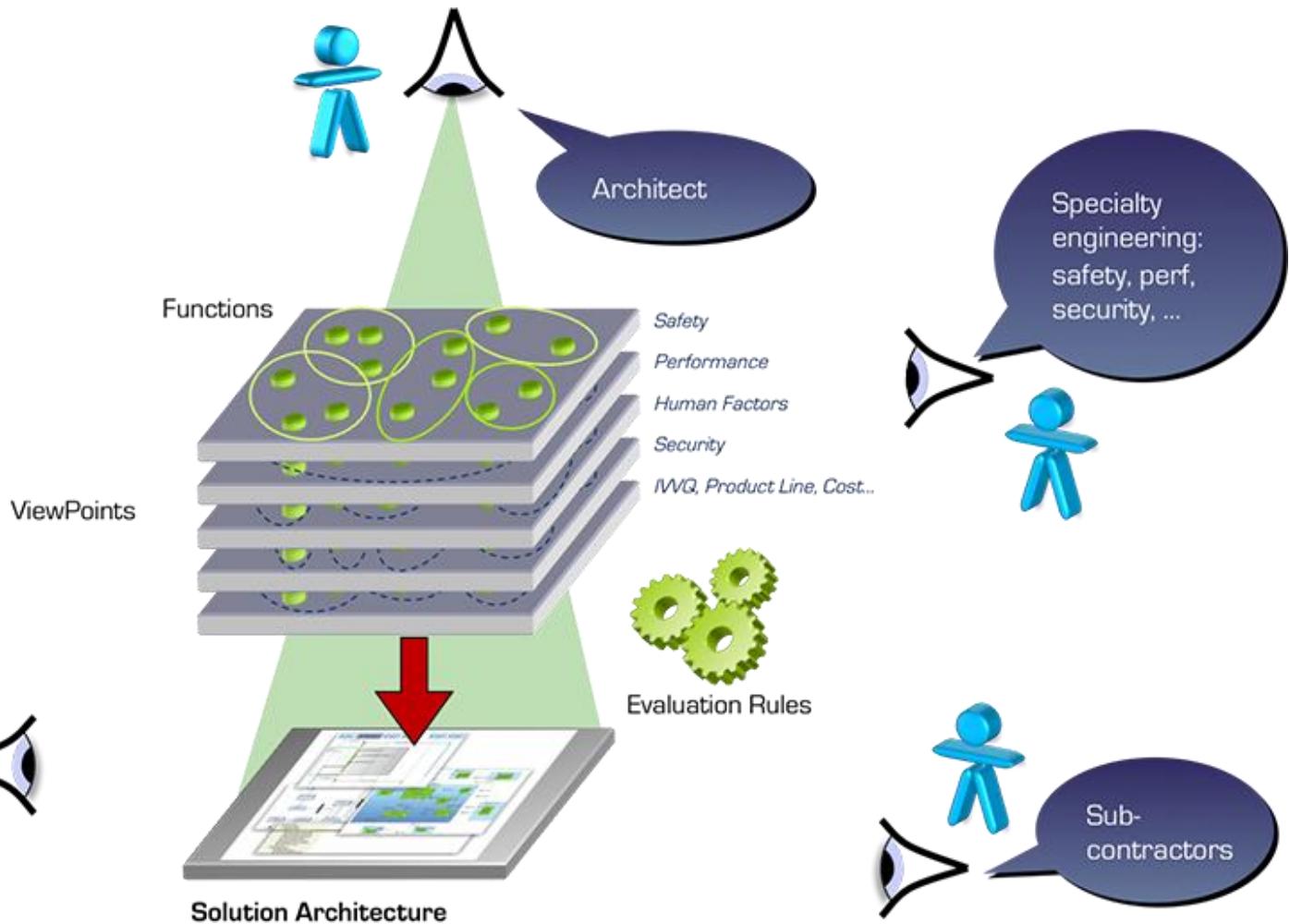


What the users of the system need to accomplish

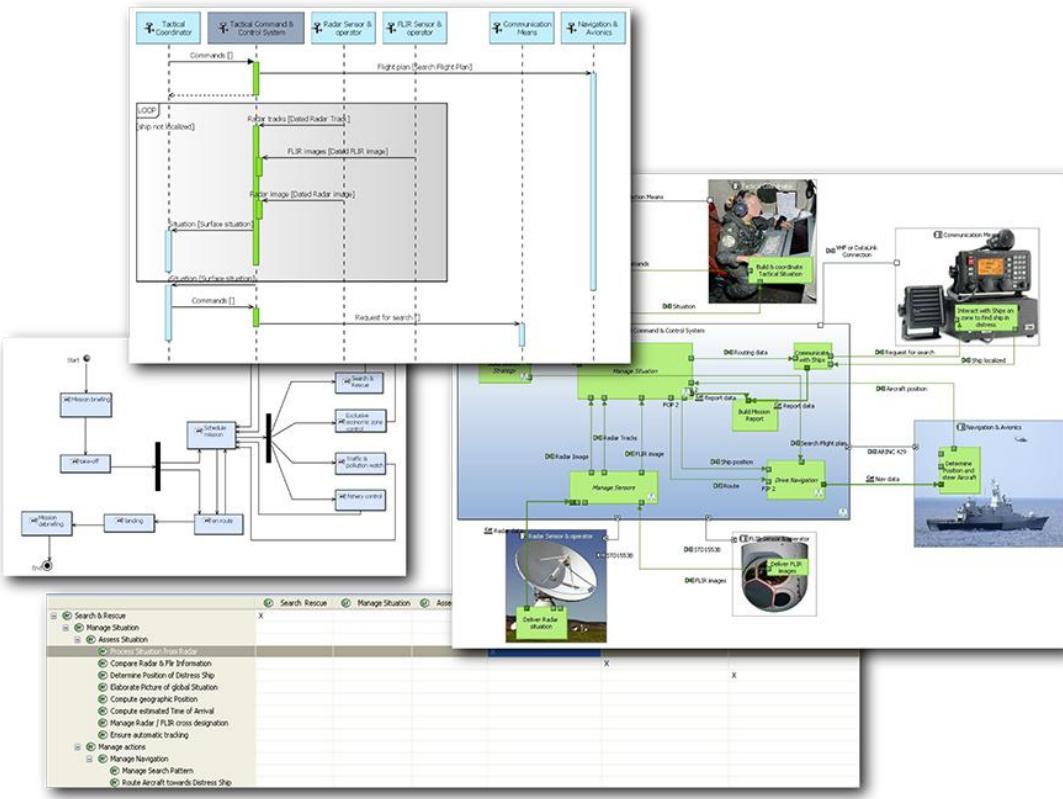
What the system has to accomplish for the users

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
Currently being open sourced

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]
        A14[Ship position]
        A15[Ship]
        A16[Commands]
        A17[Assess Situation]
        A18[Acquire FLIR Image]
        A19[Acquire radar Image]
        A20[Acquire radar tracks]
        A21[Manage Rescue Means]
        A22[Drop time bomb]
        A23[Manage Situation]
        A24[Route Aircraft towards Distress Ship]
        A25[Communicate with Ships]
        A26[Determine Position and steer Aircraft]
    end
    subgraph "Distress Ship"
        direction TB
        D1[Manage Rescue Means]
        D2[Drop time bomb]
        D3[Manage Situation]
        D4[Assess Situation]
        D5[Acquire FLIR Image]
        D6[Acquire radar Image]
        D7[Acquire radar tracks]
        D8[Ship]
        D9[Ship position]
        D10[Commands]
        D11[Search Zone]
        D12[Consolidated tracks]
        D13[Commands]
        D14[Drop time bomb]
        D15[Manage Situation]
        D16[Route Aircraft towards Distress Ship]
        D17[Communicate with Ships]
        D18[Determine Position and steer Aircraft]
    end
    A1 --> A2
    A2 --> A3
    A3 --> A4
    A4 --> A5
    A4 --> A6
    A4 --> A7
    A5 --> A6
    A5 --> A7
    A6 --> A7
    A7 --> A8
    A8 --> A9
    A9 --> A10
    A10 --> A11
    A11 --> A12
    A12 --> A13
    A13 --> A14
    A14 --> A15
    A15 --> A16
    A16 --> A17
    A17 --> A18
    A18 --> A19
    A19 --> A20
    A20 --> A21
    A21 --> A22
    A22 --> A23
    A23 --> A24
    A24 --> A25
    A25 --> A26
    A26 --> A1
    D1 --> D2
    D2 --> D3
    D3 --> D4
    D4 --> D5
    D4 --> D6
    D4 --> D7
    D5 --> D6
    D5 --> D7
    D6 --> D7
    D7 --> D8
    D8 --> D9
    D9 --> D10
    D10 --> D11
    D11 --> D12
    D12 --> D13
    D13 --> D14
    D14 --> D15
    D15 --> D16
    D16 --> D17
    D17 --> D18
    D18 --> D19
    D19 --> D20
    D20 --> D21
    D21 --> D22
    D22 --> D23
    D23 --> D24
    D24 --> D25
    D25 --> D26
    D26 --> D1
    
```

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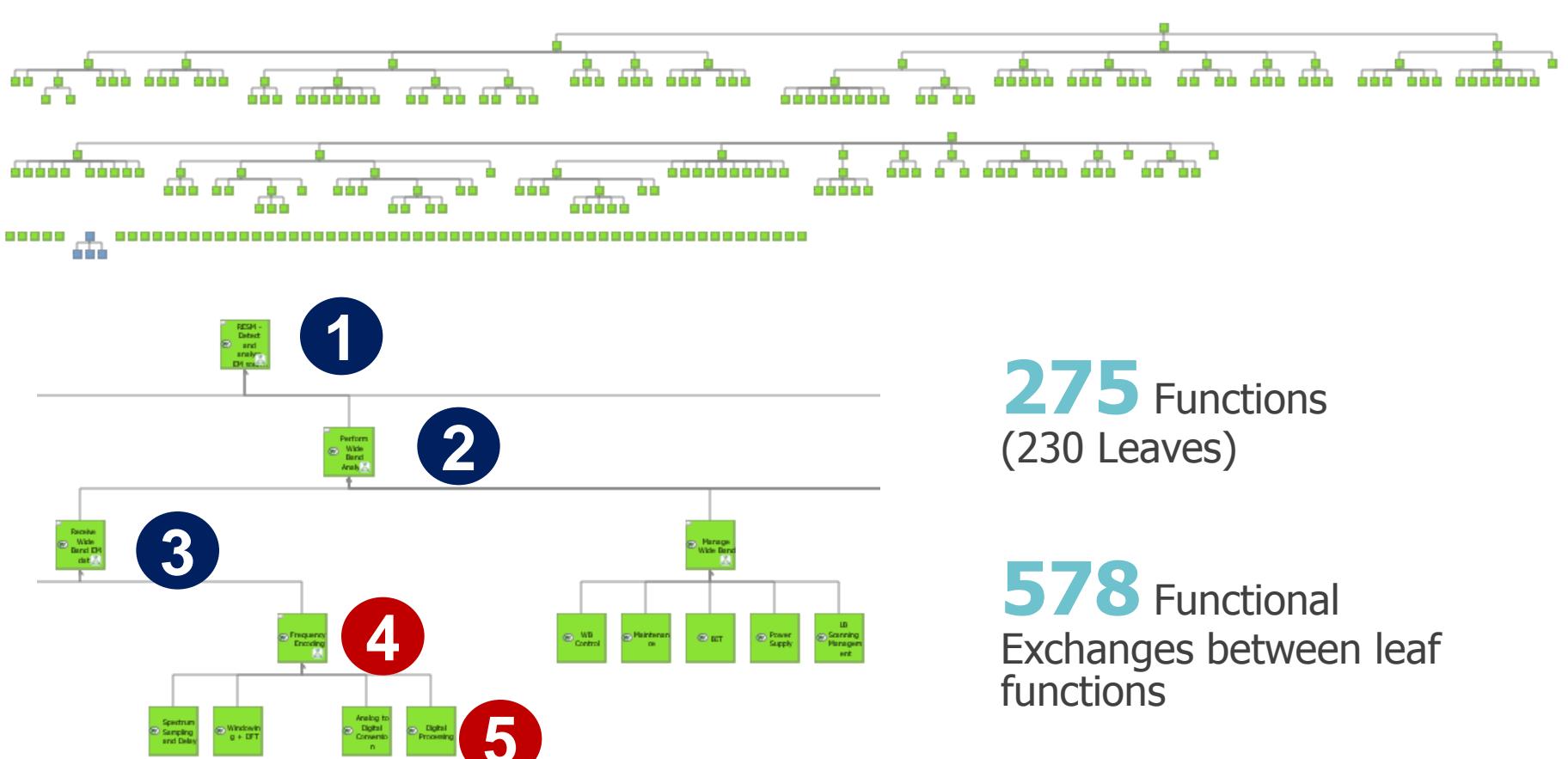
Use Case 1: Managing System Design Complexity

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



275 Functions
(230 Leaves)

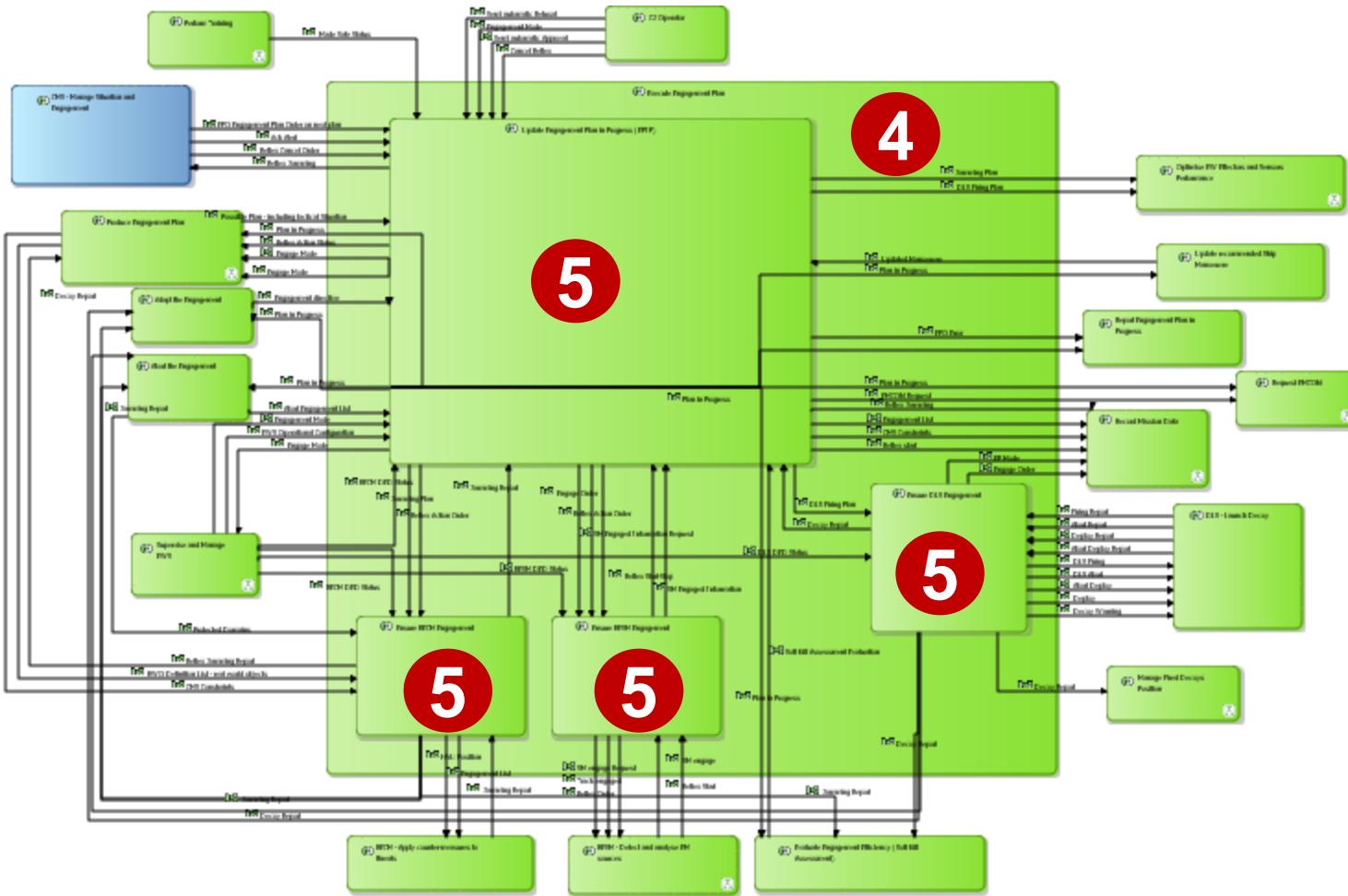
578 Functional
Exchanges between leaf
functions

5 levels of decomposition

third party

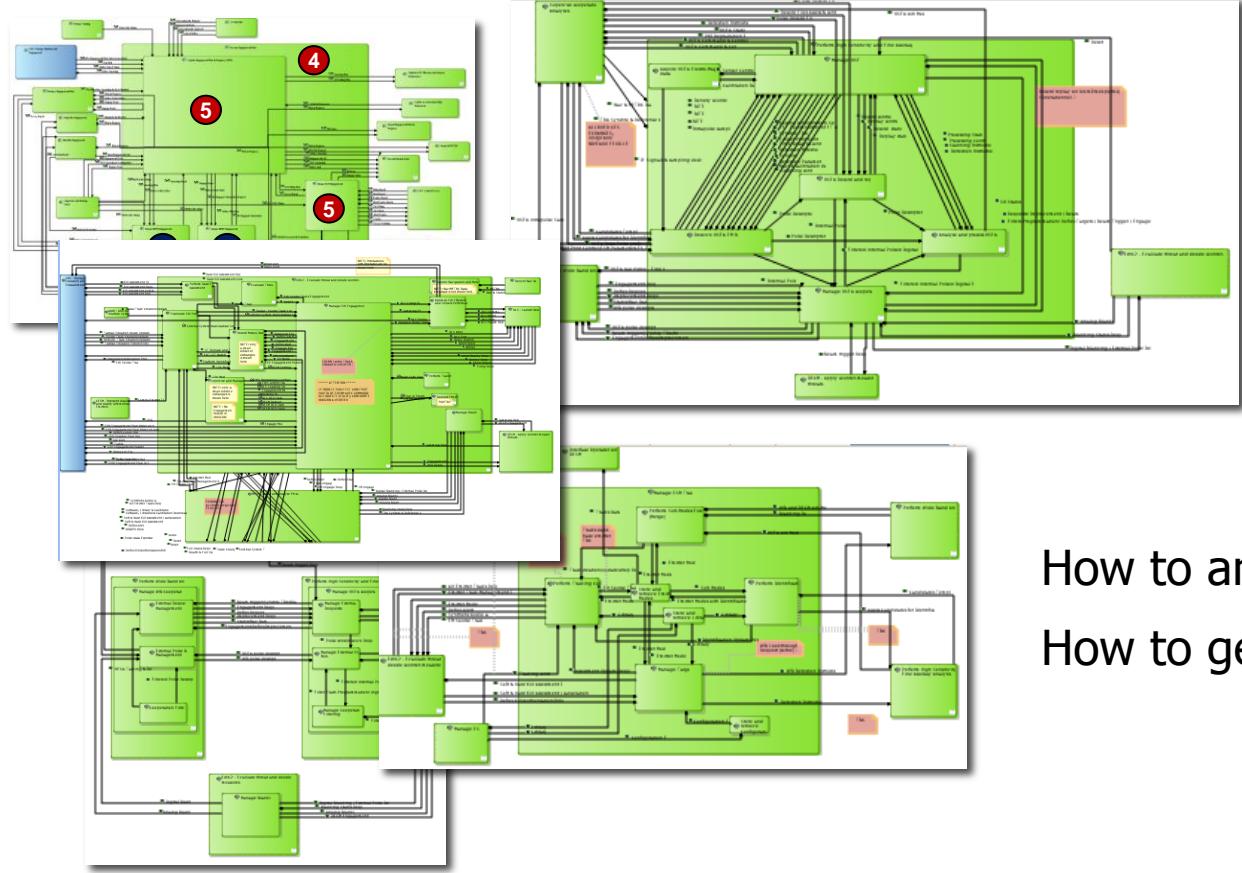
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Contextual Diagrams: Low-level internals



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X 40

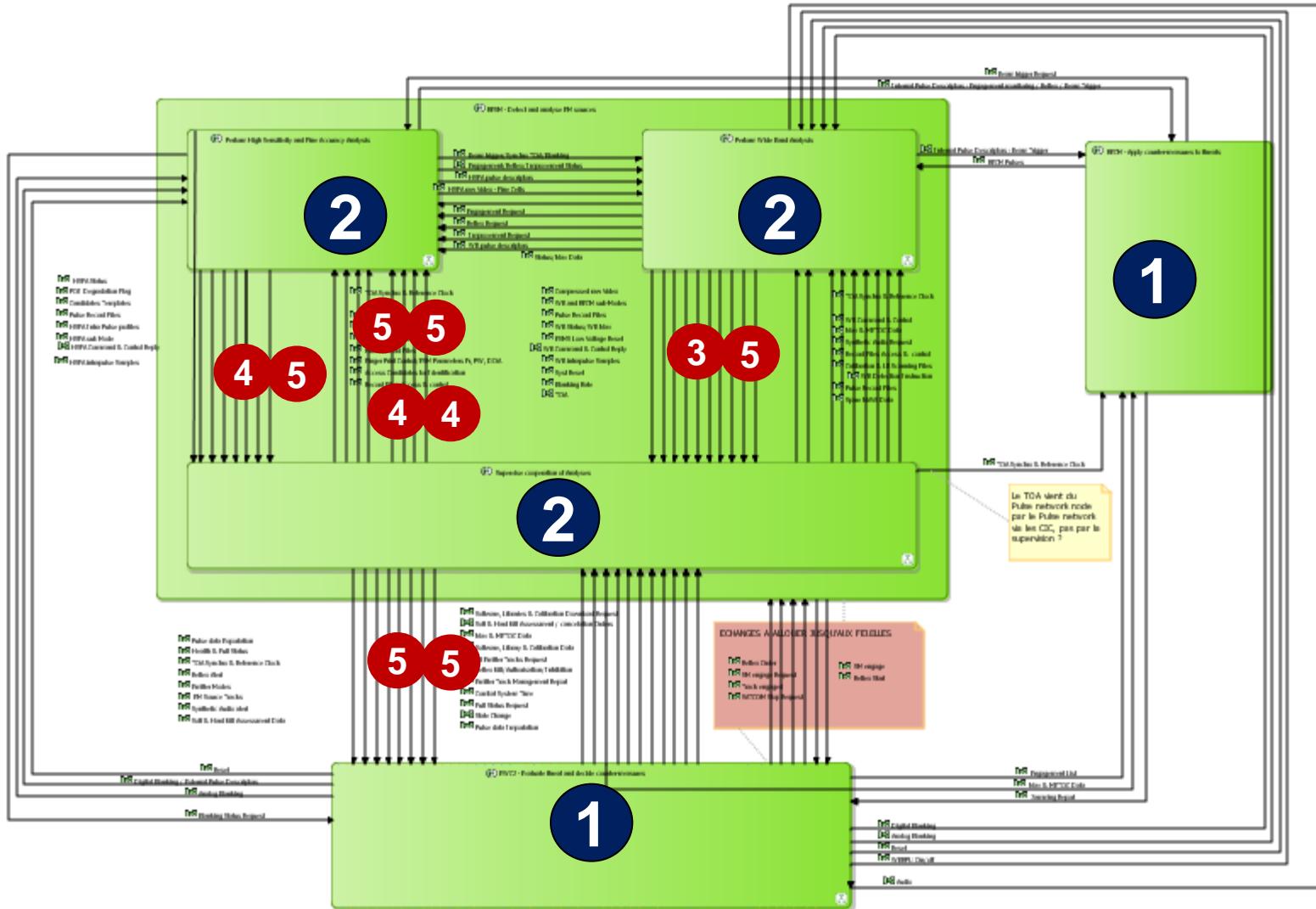
How to analyze transverse topics?
How to get transverse overviews?

Challenge: Build and maintain simplified views

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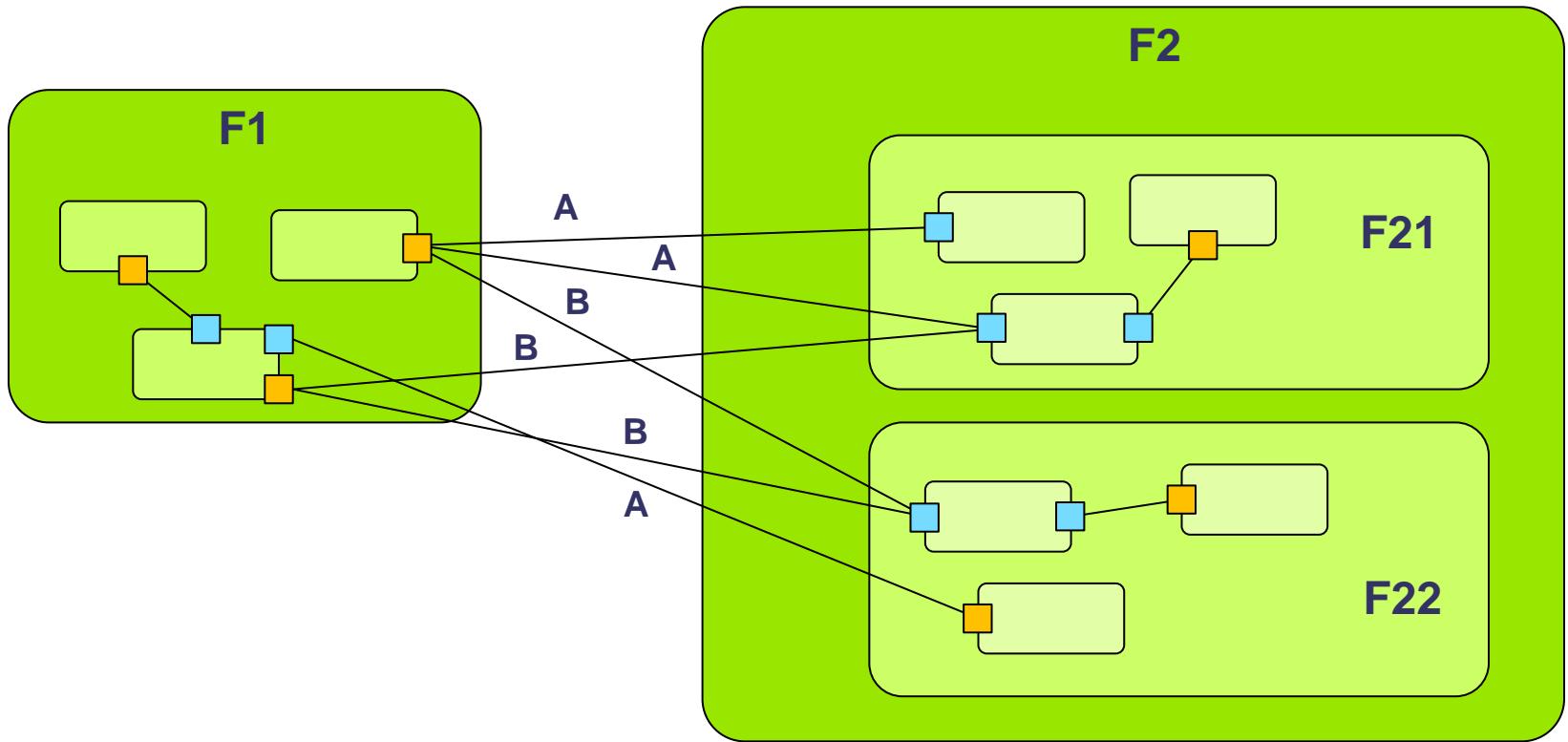
Computed Diagrams: High-level Functions, Low-level Exchanges



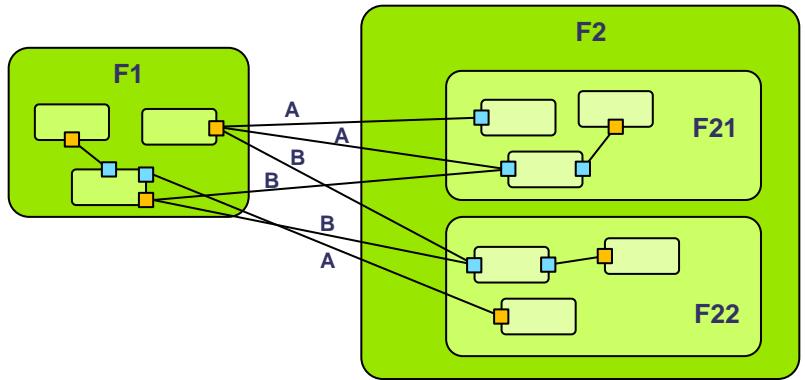
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MODEL

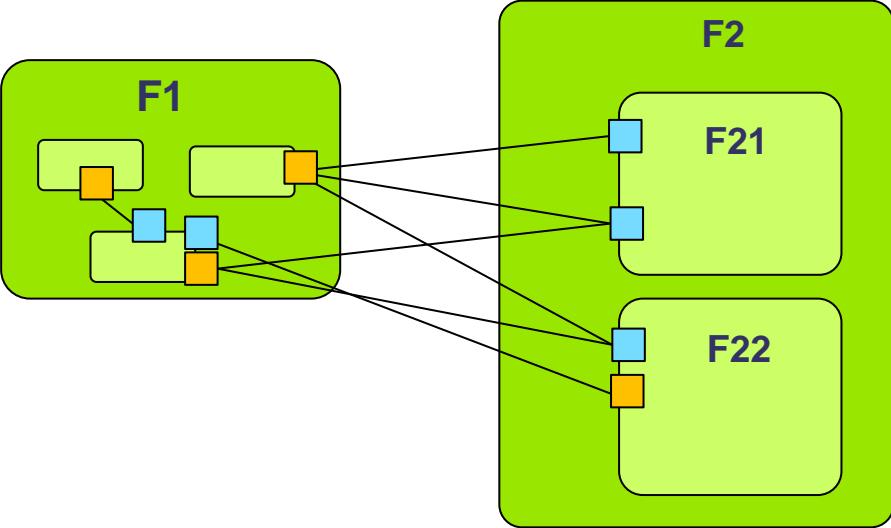


MODEL



**THEORY:
DELEGATION**

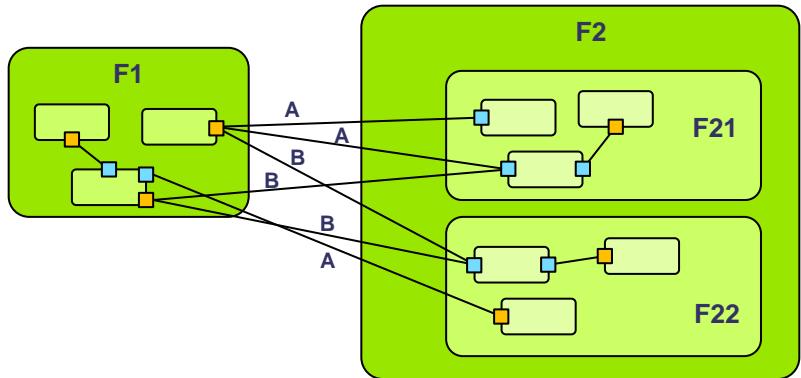
VIEW



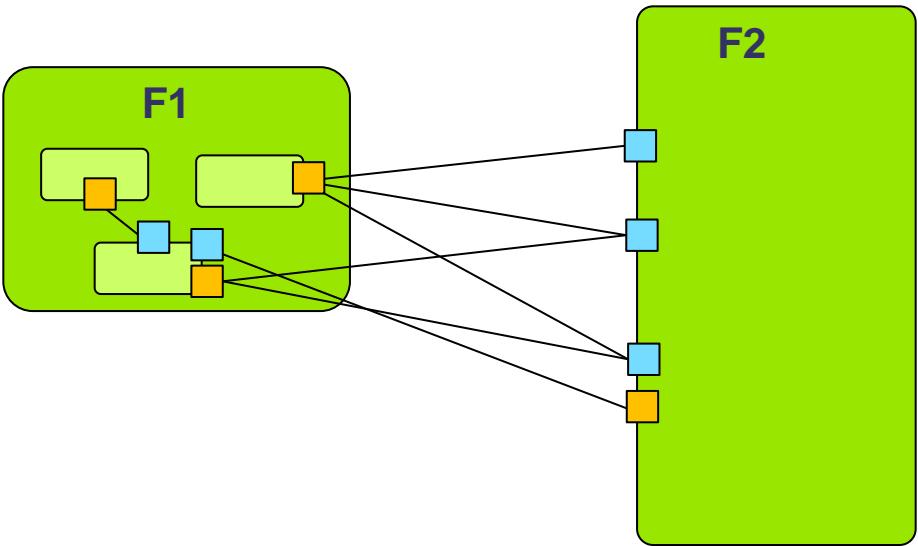
Children of F21 and F22 not displayed

Ports on F21 and F22 are graphically computed

MODEL



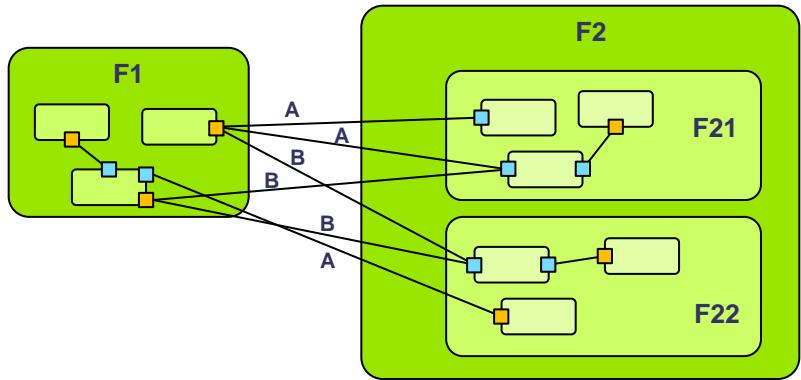
VIEW



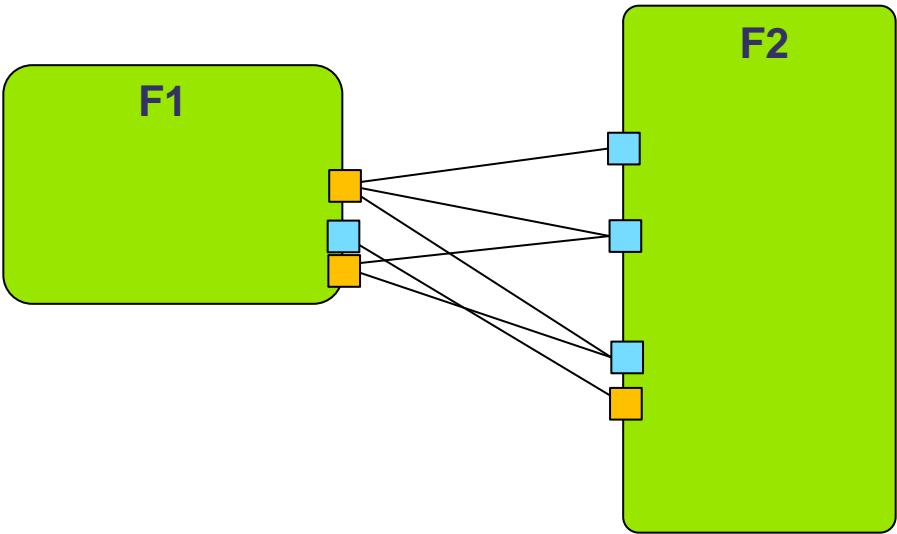
Children of F2 not displayed

Ports on F2 are graphically computed

MODEL



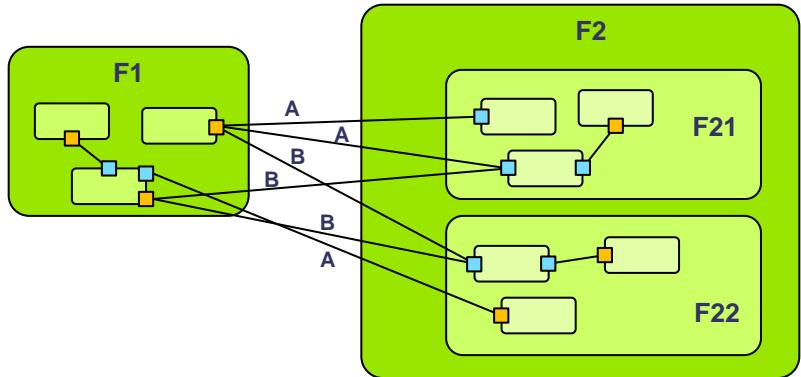
VIEW



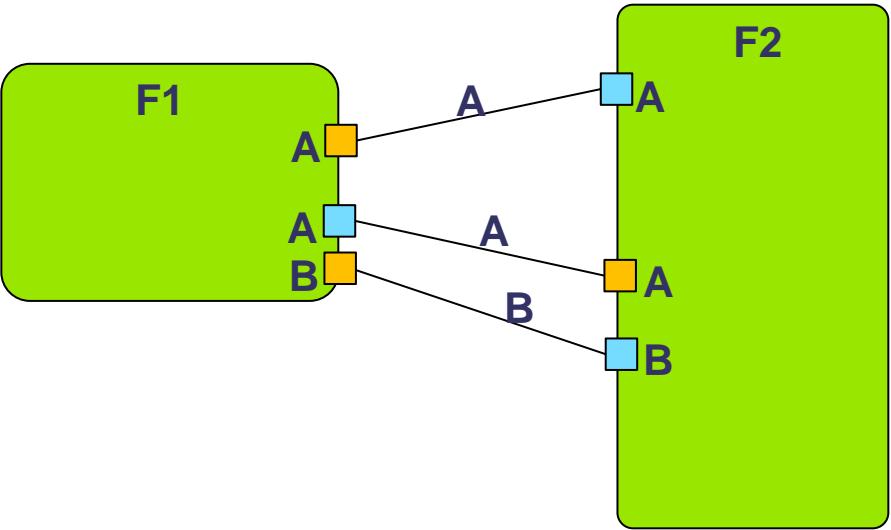
Children of F1 and F2 not displayed

Ports on F1 and F2 are graphically computed

MODEL



VIEW



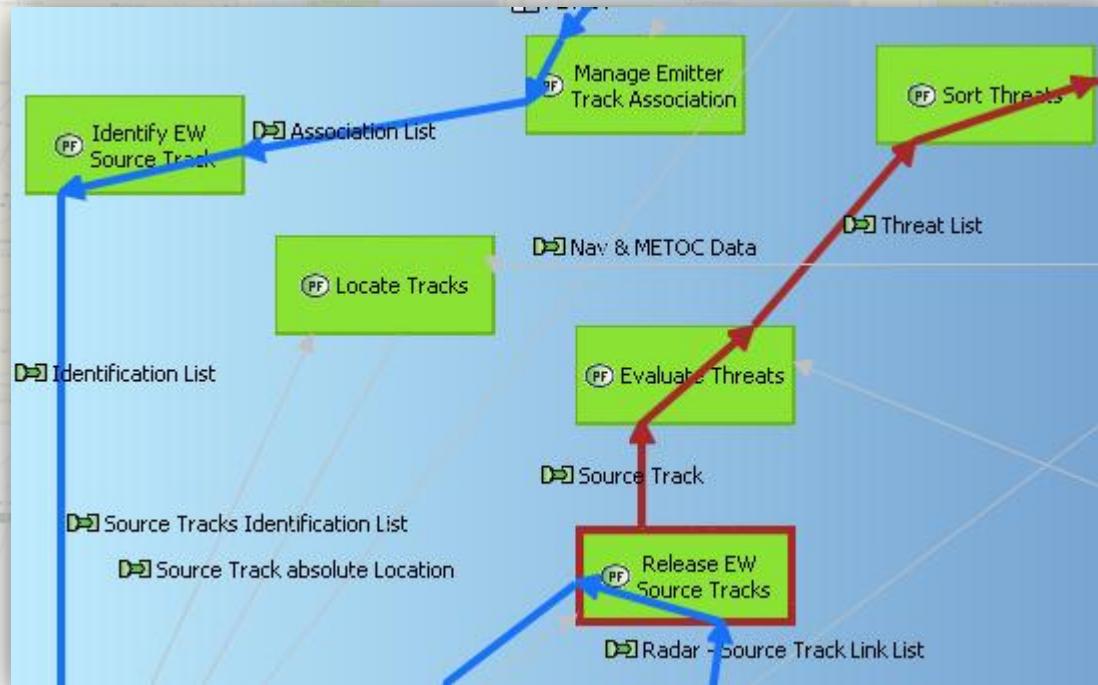
Tag-based simplification mechanism

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

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Managing System Design Complexity: Global Overview



End-to-end visualization of Functional Chains



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

Context

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

MBSE usage

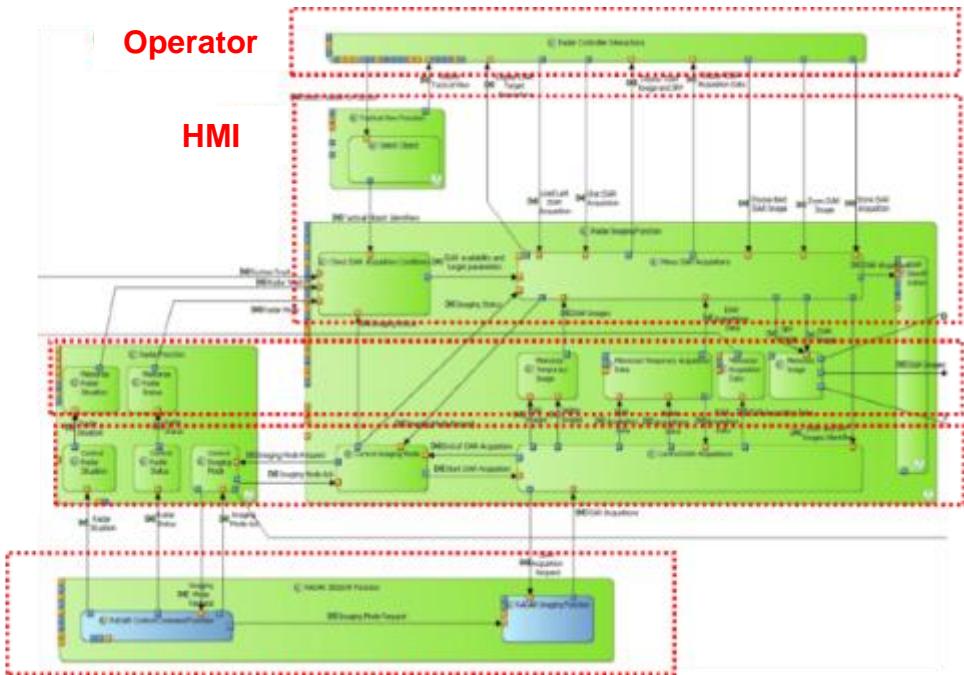
- Up-to-date model of the delivered System available
- Modification of the model in order to:
 - **Estimate feasibility, cost and risks**
 - Drive developments and IWVQ
- **Product line** management



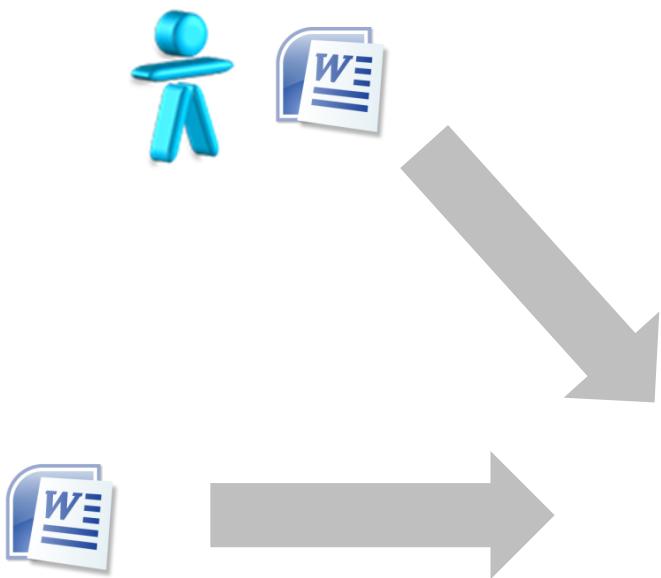
A regular reading pattern

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

DATA
PROCESS/
INTERFACES
EQUIPMENT

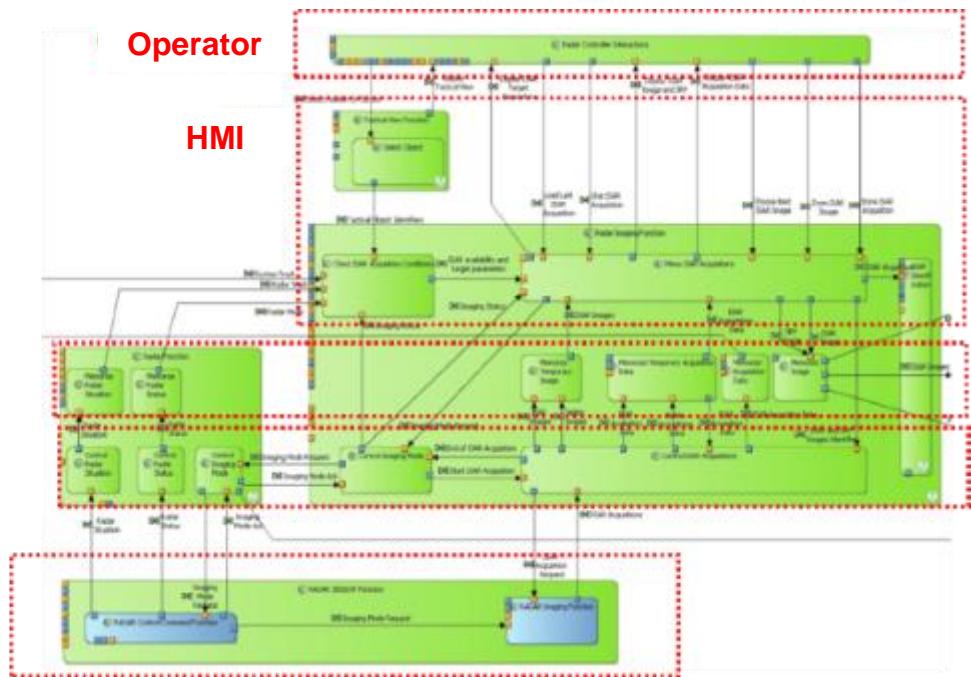


SSS: Need

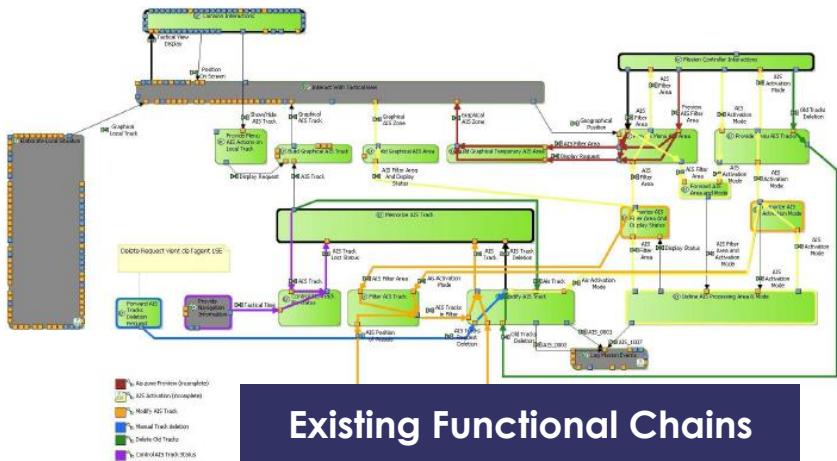
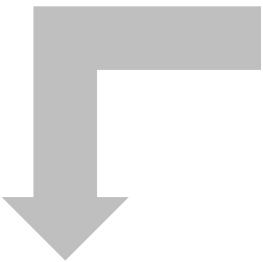


PIDS: Reverse
Engineering from
Software Specification

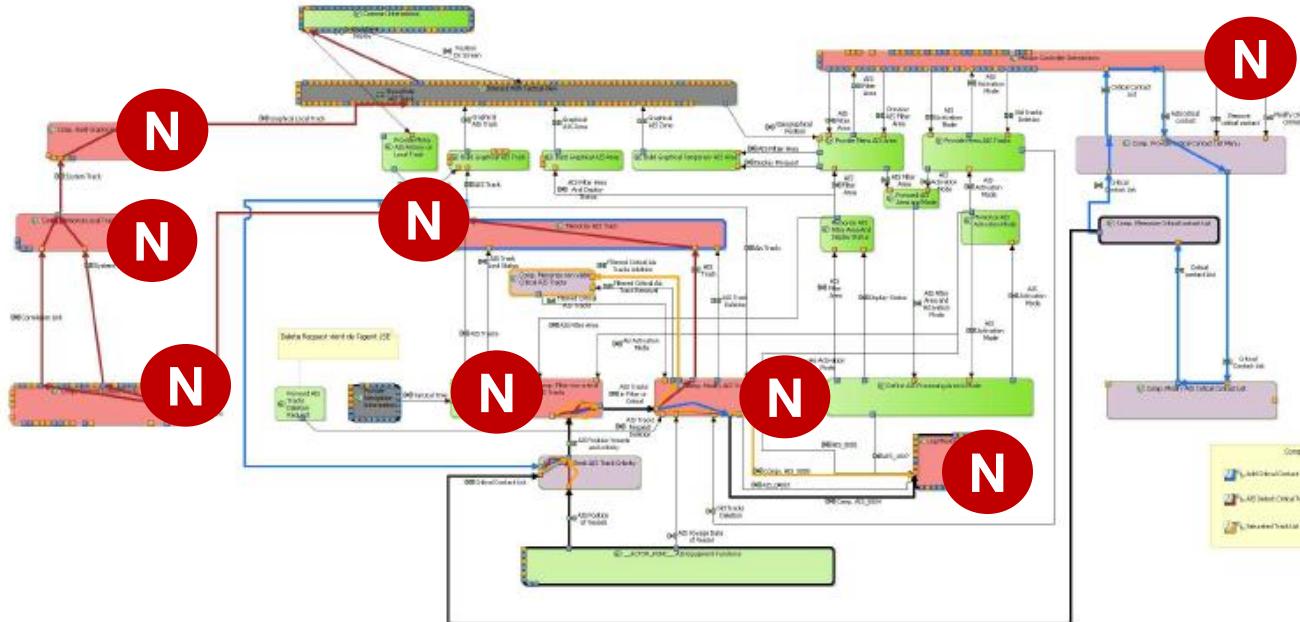
DATA
**PROCESS/
INTERFACES**
EQUIPMENT



New Customer needs



Existing Functional Chains



N
Impacted Functions



New Functional Chains

COST Analysis Viewpoint

Elementary work decomposition

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

Computed Data: Estimated Cost

**Capella Outputs
(model export)**

The screenshot shows a Microsoft Excel spreadsheet with two main sections highlighted:

- Fct 9** (Red Box): This section contains a table with various metrics. The columns include N, O, P, Q, R, AI, AJ, AK, AL, AM, and AP, AQ, AR. The rows include Panneaux, Fonctions chiffrées, Complexité, and Totaux.
- Computed Data: Estimated Cost** (Blue Box): This section contains a larger table with more detailed data. It includes columns for AP, AQ, AR, and various reuse metrics like 'à développer (Exemple)', '40% signifi.', 'Reuse et TU avec', and 'Reuse et TU avec Reuse et'. The rows correspond to the metrics in the Fct 9 table.



Use Case 3: Multi-Level Engineering

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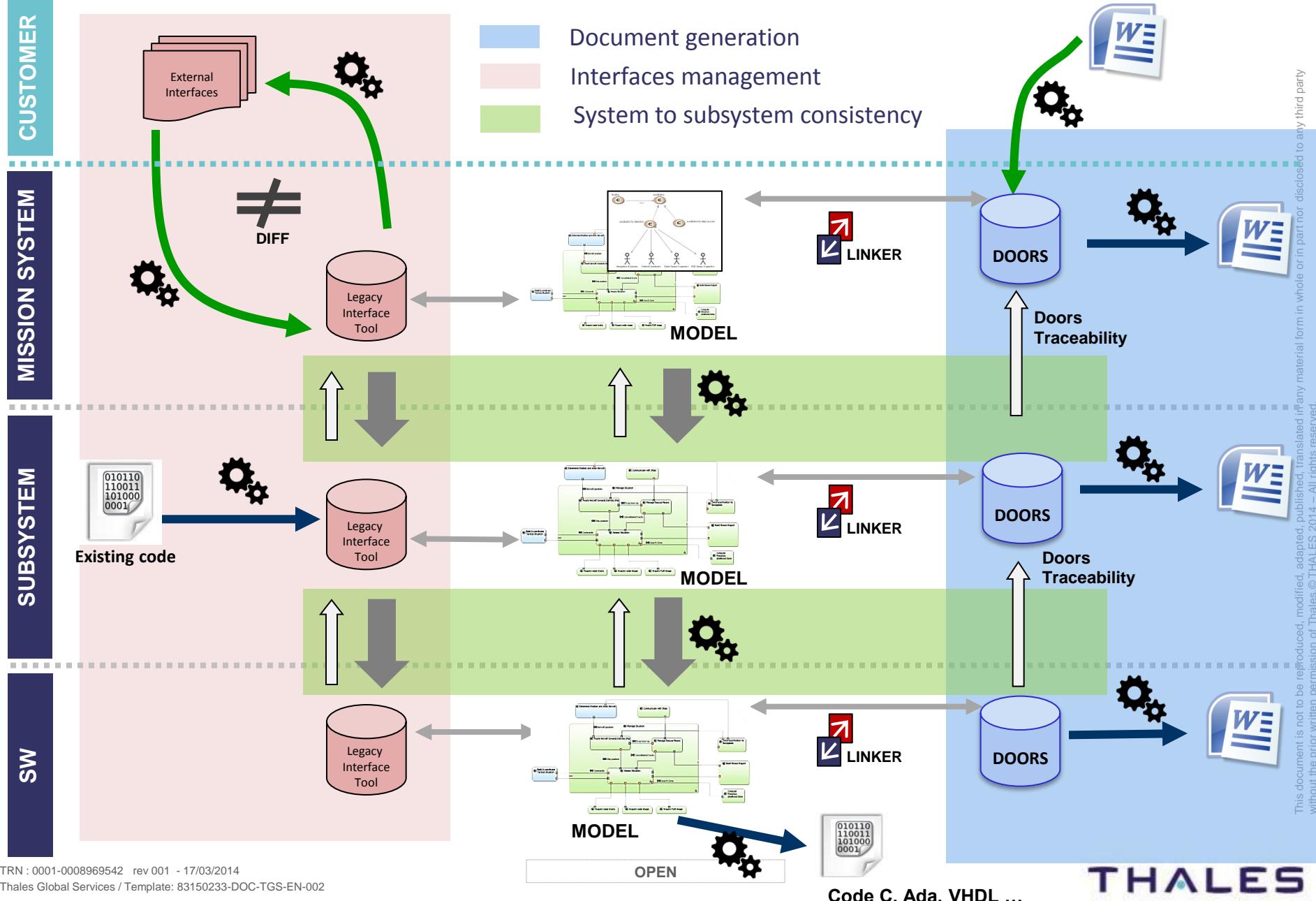
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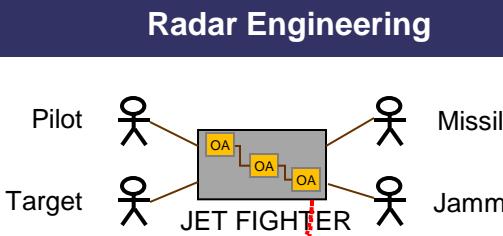
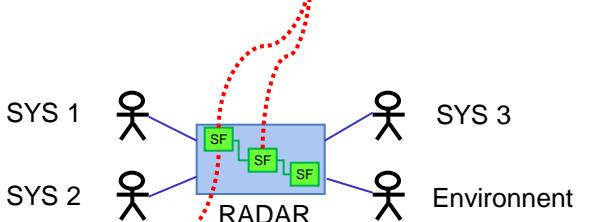
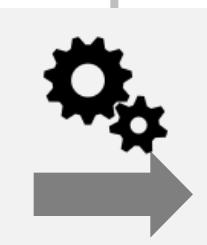
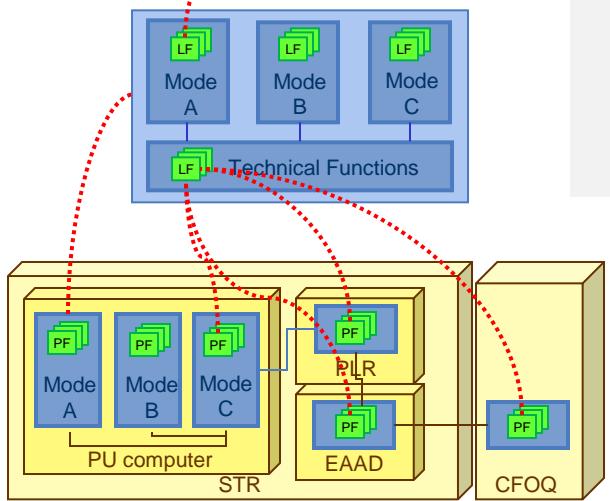
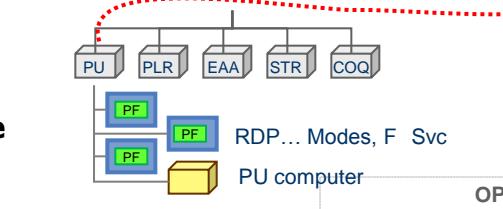
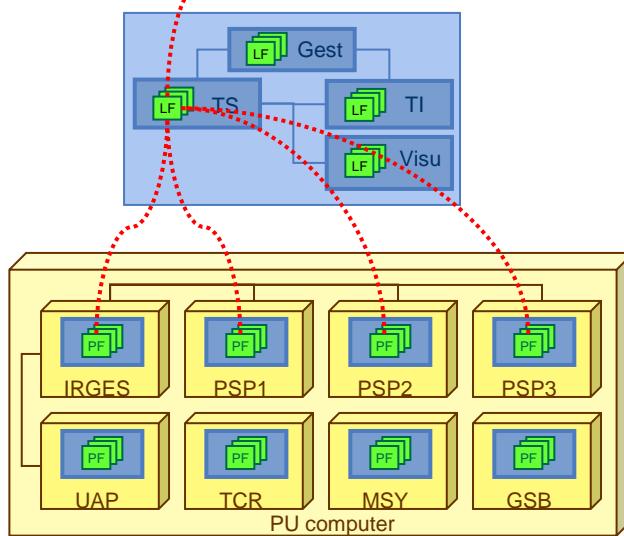
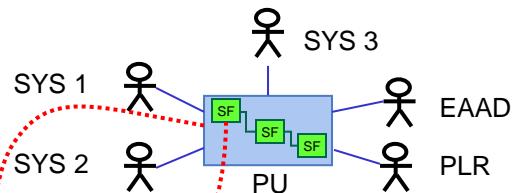
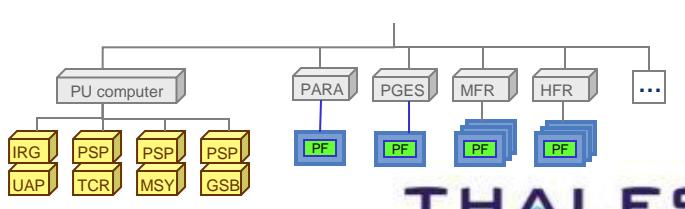
Context



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



Operational Analysis**System Analysis****Logical Architecture****Physical Architecture****Processing Unit Engineering****Product Breakdown Structure**

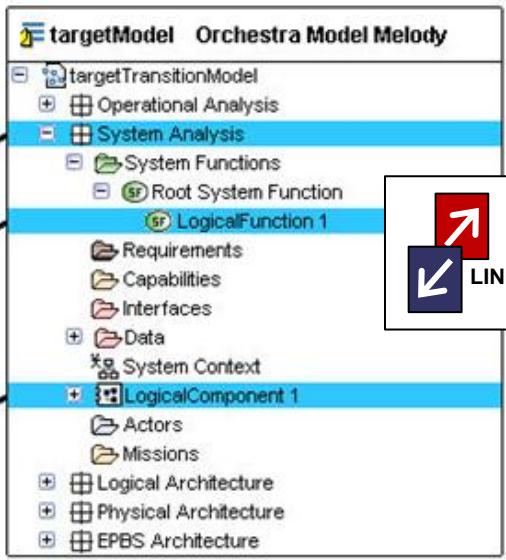
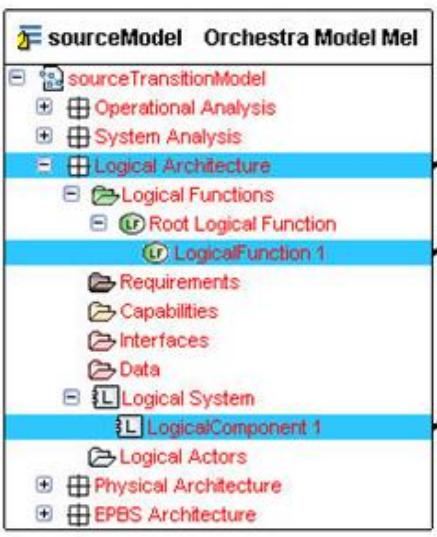
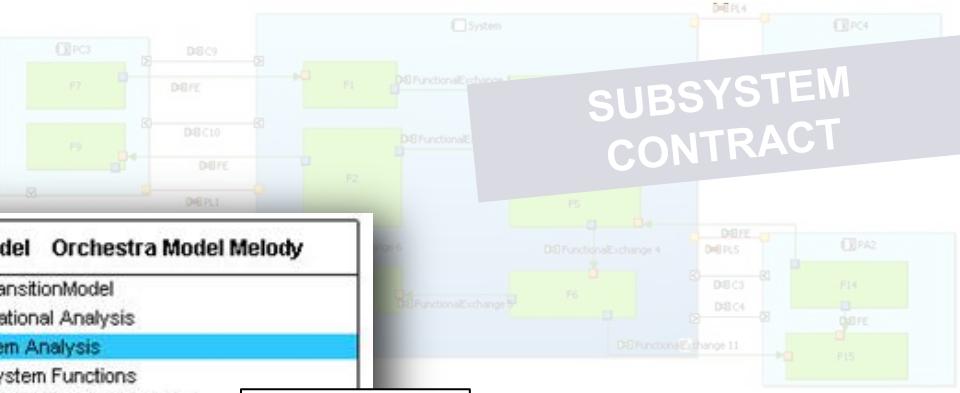
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System Physical Architecture

Subsystem Need Analysis



CO-EN

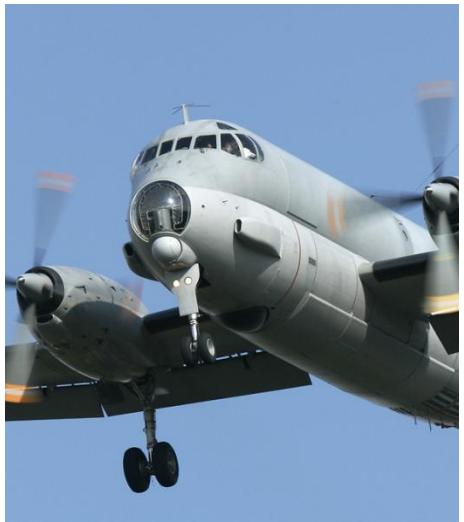
**SUBSYSTEM CONTRACT****SUBSYSTEM ARCHITECTURAL DESIGN INITIALIZED**

Subsystem Physical Architecture

**Computed system - subsystem traceability**

OPEN

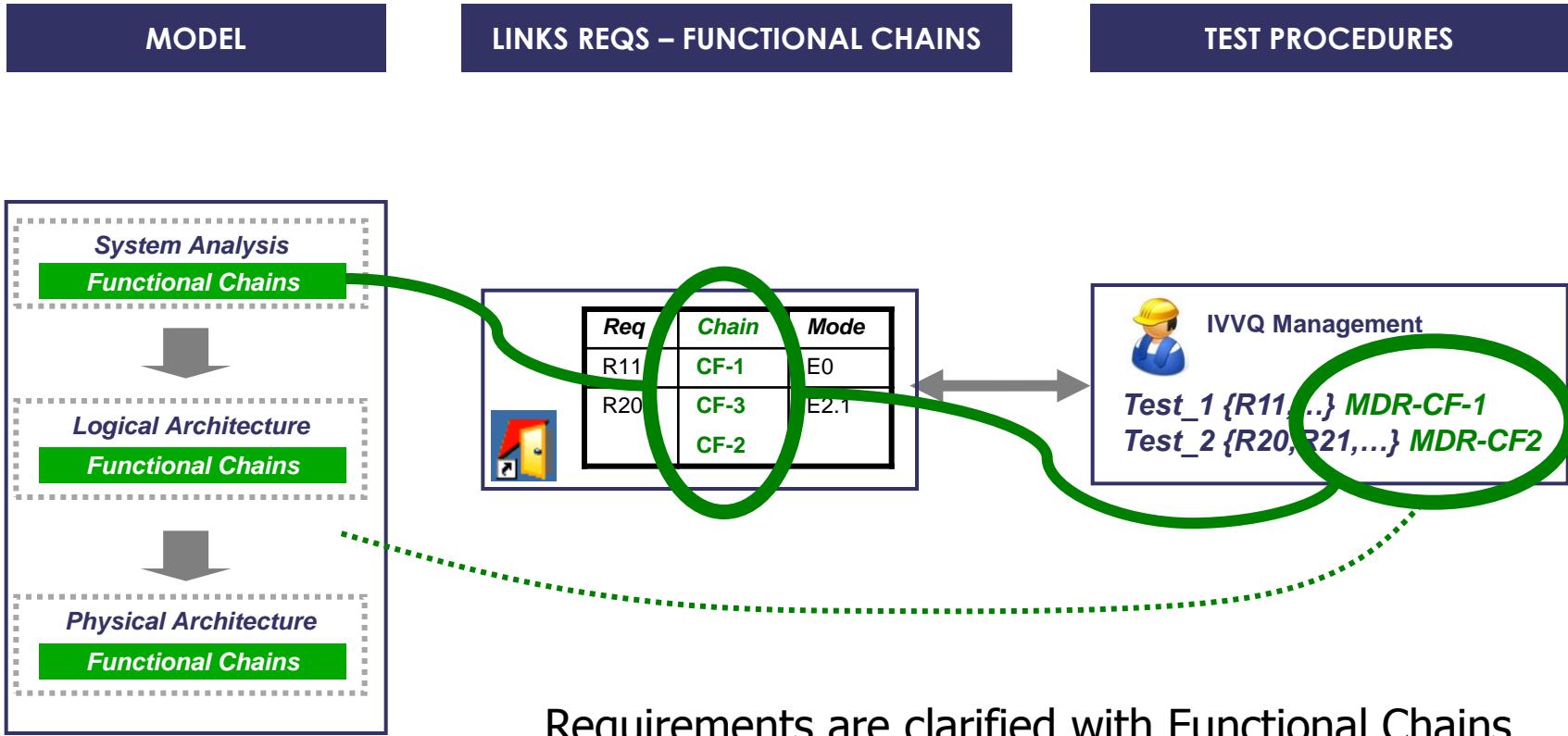
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Use Case 4: Model-driven IVV

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IVV Strategy: Requested Versions / Developed Versions

Version

- REQUESTED
- DEVELOPED
- TEST
- CR DIAGNOSED
- CR CORRECTIVE

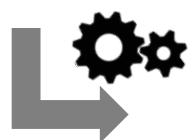
Filters

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

Elements

- AMASCOS
- AMASCOS
- System Functions
- Root System Function
- SEN - IFF - Create IFF File using IFF plot
- SEN - IFF - Enter IFF search parameters in sectorial Mode
- SEN - IFF - IFF RF Management
- SEN - IFF - IFF State Control
- SEN - IFF - Select IFF RF Recognition Mode
- SEN - RAD - Control Local Antenna
- SEN - RAD - Control PACAR Frequency plan
- SEN - RAD - Control Radar mode
- SEN - RAD - Control Radar Transmission
- SEN - RAD - Display Radar 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 - Ede TV5 area
- SEN - RAD - Radar tracks processing

Define operational content expected for each project milestone



Version

- REQUESTED
- DEVELOPED
- TEST
- CR DIAGNOSED
- CR CORRECTIVE

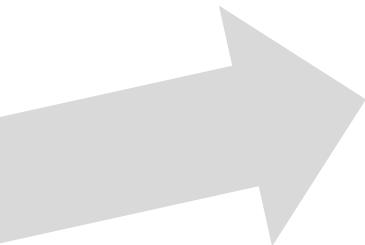
Filters

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

Elements

- 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

Deduce functional content and components to be delivered



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

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

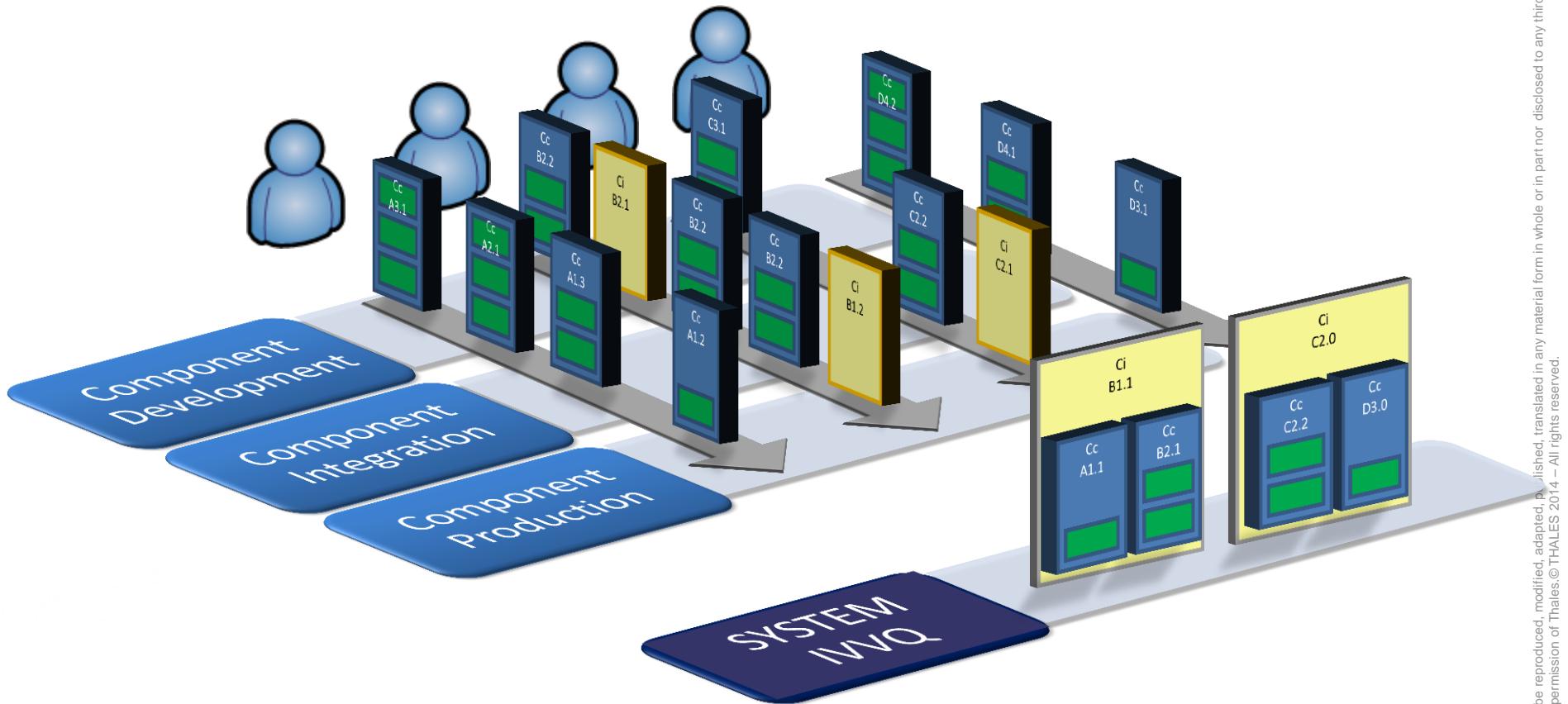
Elements

- AMASCOS
- AMASCOS
- 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

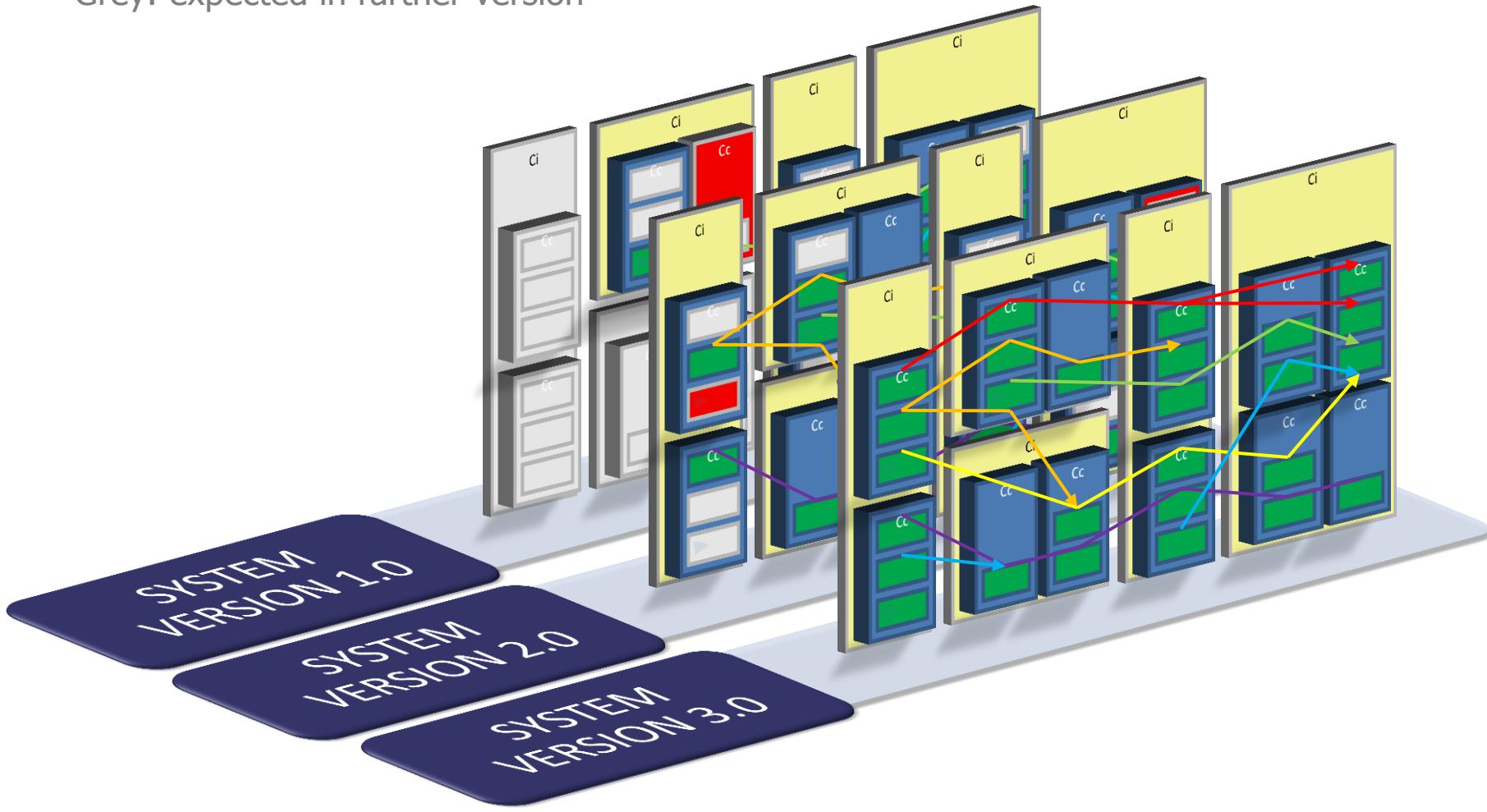
Mastering System & Components Configurations

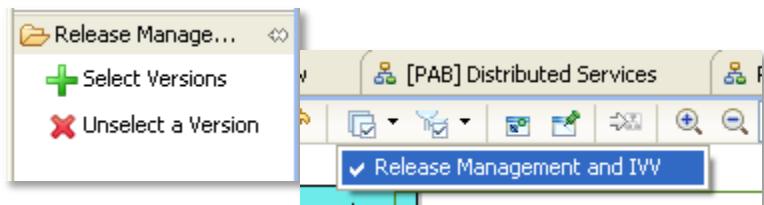
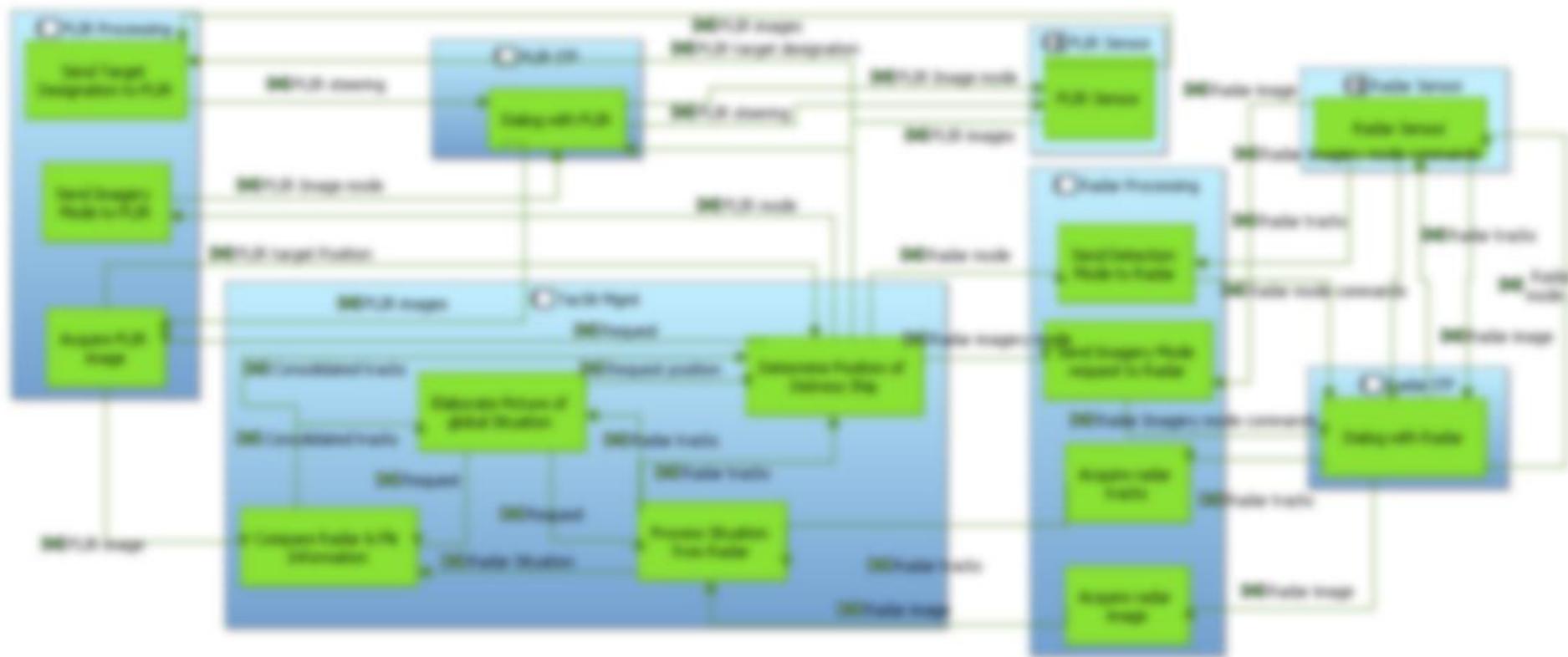
Blue: Software
Yellow: hardware



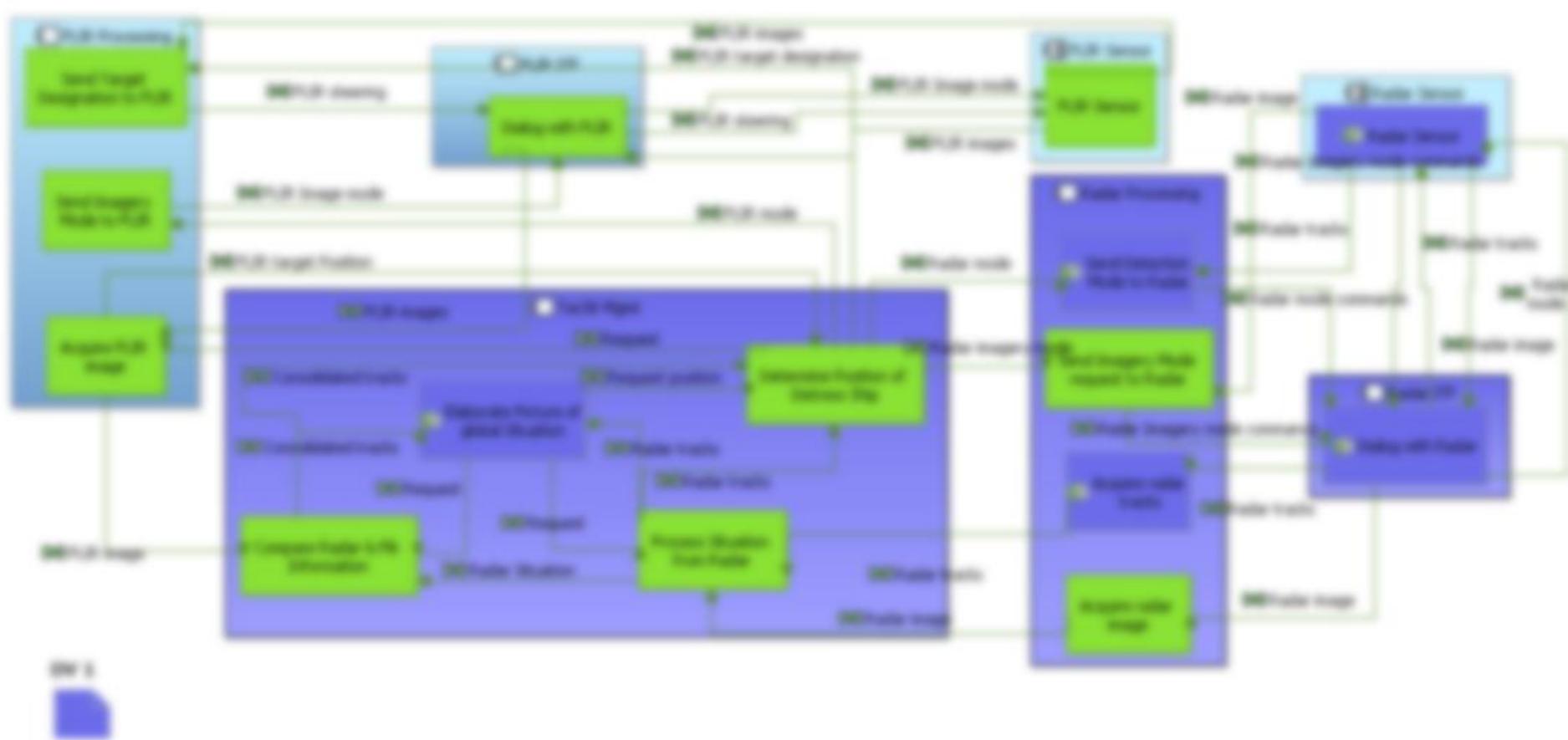
Red: Delayed, missing

Grey: expected in further version

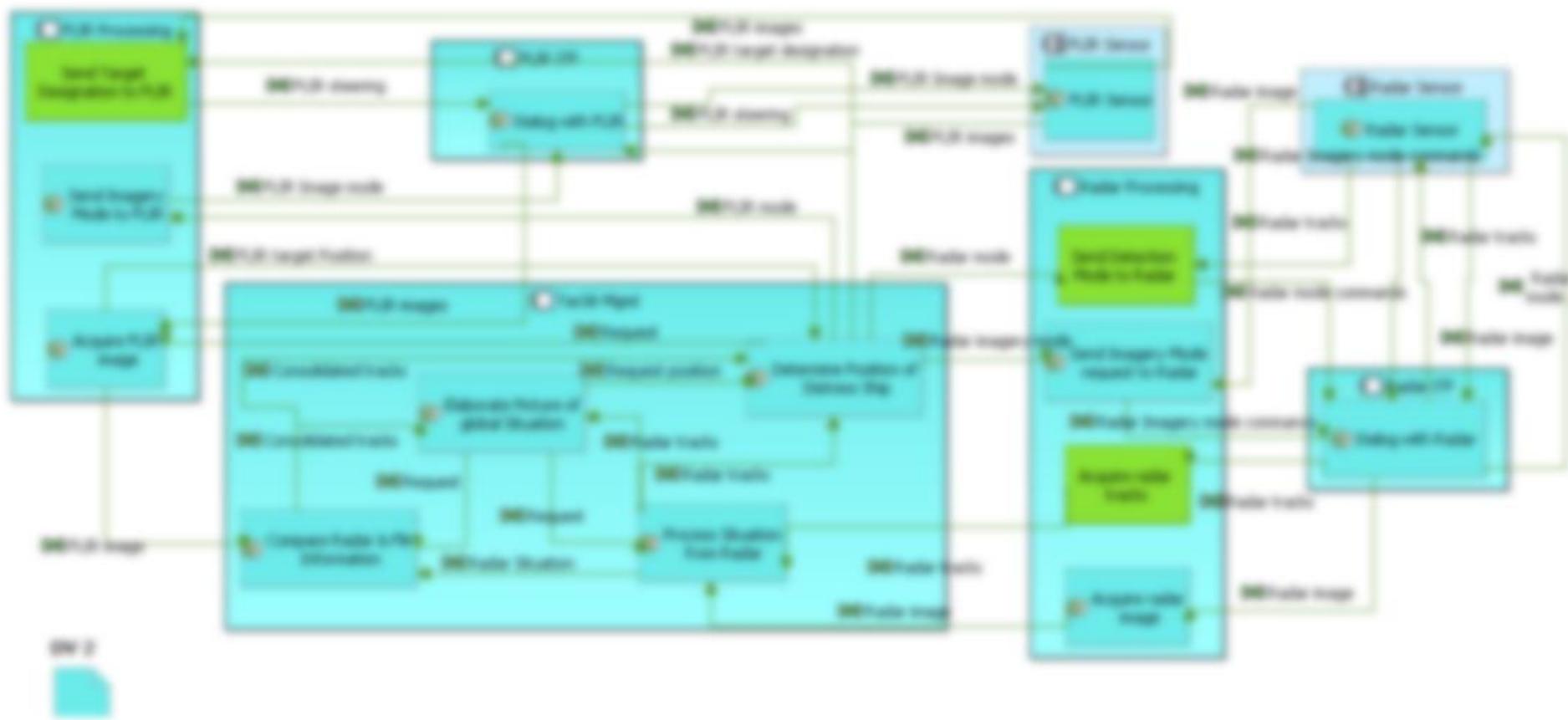




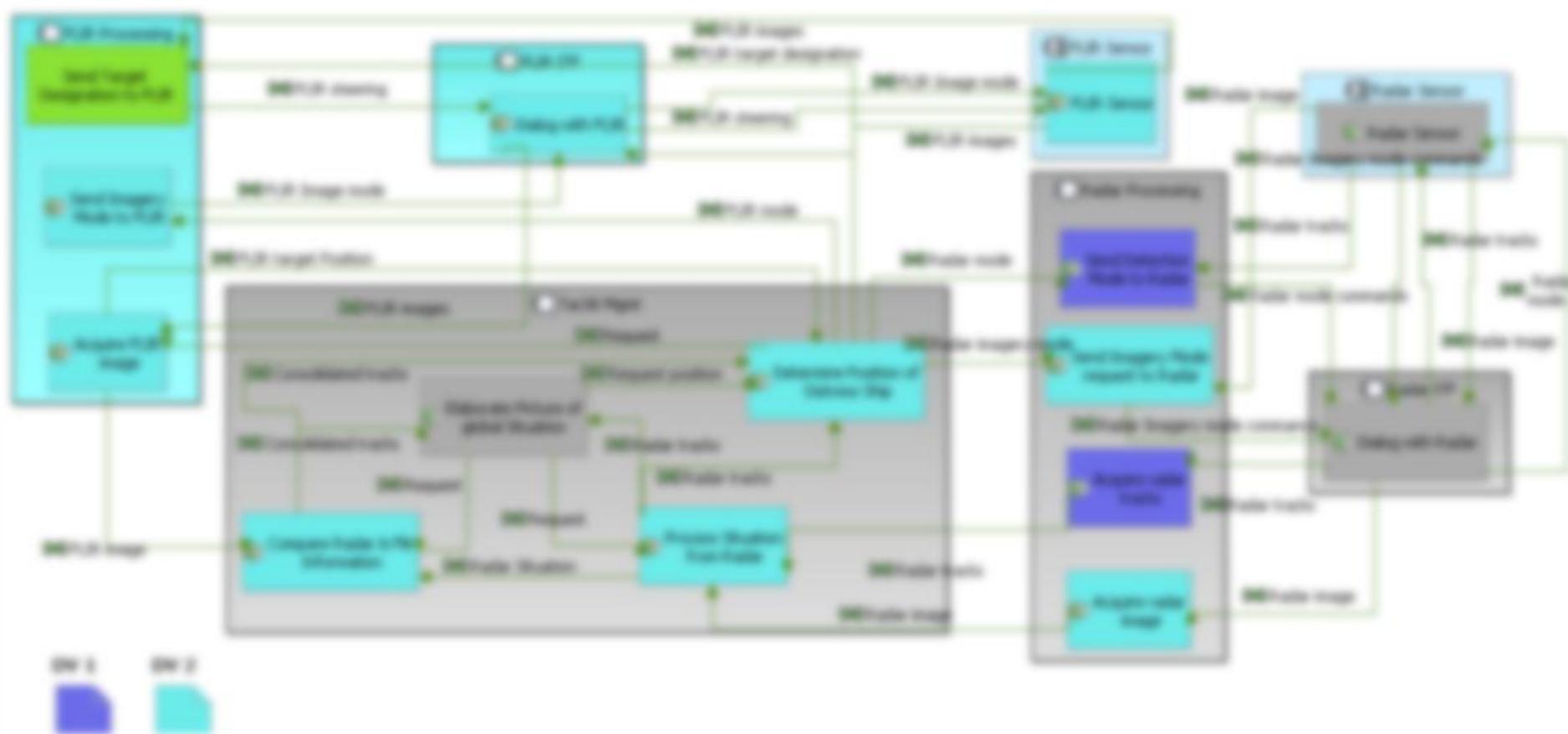
Release management viewpoint:
Automated visualization of versions



Developed Version 1
Available elements in BLUE



Developed Version 2
Available elements in CYAN



Developed Versions 1 & 2
Common available elements in GREY

Compare Planned vs Developed versions

Properties **IWWQ [AMASCOS]** **REALIZATION [FREMM]** **DDV - Root Physical Function [FREMM]** **Console** **DAE Property View** **GLOBAL [AMASCOS]** **Semantic Browser**

Config Analysis Version content **Queries**

Category	Queries				
ES analysis	<input type="checkbox"/> List all DV provided elements with E5 complement				
	<input type="checkbox"/> List all needed elements to integrate this DV				
	<input type="checkbox"/> Compare needed elements to integrate this DV and all elements provided by the Enabling System Real se				
	<input type="checkbox"/> Compare ES elements with the ES theoretic defined by the set of requiring DV				
	<input type="checkbox"/> Compare needed elements between two RV				
	<input type="checkbox"/> Compare requested elements between two RV				
	<input type="checkbox"/> Compare developed elements between two DV				
	<input type="checkbox"/> Compare provided elements between two DV				
	<input type="checkbox"/> Compare : DV developed elements versus RV needed elements				
	<input type="checkbox"/> Compare : DV developed elements with ES complement versus RV needed elements				
DV / DV comparison	<input type="checkbox"/> Compare : DV provided elements versus RV requested elements				
	<input type="checkbox"/> Compare : DV provided elements with E5 complement versus RV requested elements				
	<input type="checkbox"/> Compare : DV provided elements with E5 complement versus RV needed elements				
	<input type="checkbox"/> Export to graphml for scheduling representation				
	<input type="checkbox"/> Which expected elements are provided by this DV with E5 complement ?				
Diff C2 Version 5.1 vs Standard 0 - SEN-RAD Basic + SEN-IFF Basic					
	Version	Phase	Elements		
	C2 Version 5.1	<input type="checkbox"/> Physical Architecture			
	C2 Version 5.1	<input type="checkbox"/> Physical Architecture			
	C2 Version 5.1	<input type="checkbox"/> Physical Architecture			
	C2 Version 5.1	<input type="checkbox"/> Physical Architecture			
	C2 Version 5.1	<input type="checkbox"/> Physical Architecture			
	C2 Version 5.1	<input type="checkbox"/> Physical Architecture			
	C2 Version 5.1	<input type="checkbox"/> Physical Architecture			
	C2 Version 5.1	<input type="checkbox"/> Physical Architecture			
				<input type="checkbox"/> SEN - IFF - Create IFF Fix using IFF plot	
				<input type="checkbox"/> SEN - RAD -Control RADAR Transmission	
				<input type="checkbox"/> SEN - RAD -Edit TWS area	
				<input type="checkbox"/> SEN - IFF - Select IFF Interrogation Mode	
				<input type="checkbox"/> SEN - RAD -RADAR tracks processing	
				<input type="checkbox"/> SEN - RAD -Display RADAR video on CKD	
				<input type="checkbox"/> SEN - IFF - Delete IFF Fix	
				<input type="checkbox"/> SEN - RAD -Enter IFF search parameters in sectorial Mode	
				<input type="checkbox"/> SEN - RAD -Control RADAR frequency plan	

Send query **Clear All** **Export** **Display on Diagram**

22 /

Real world examples

Capella customisations

Multi-level MBSE

Measured gains on IIV

Progress Monitoring

THALES

23 /

Real world examples

Satisfy: Essential Data Prototype

Safety Rules verification Prototype

Cost estimation

Legacy Interfaces

THALES

24 /

Real world examples

Code generation

Product Line modelling

Model-driven IIV

Performance analysis

THALES

And more to come!



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

Capella Open Source Project

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

The screenshot shows the homepage of the Capella Open Source Project. At the top is a navigation bar with links for Home, About, News, Projects, Downloads, Technologies, Community, and Contact Us. Below the navigation bar are several icons representing different engineering domains: a car, a heart, a plane, a truck, a wind turbine, a network tower, and a mobile device. The main content area has a breadcrumb trail: Home / Polarsys / Capella / Capella. It features a "Project Navigation" section with links for "View", "Downloads", "Who's Involved", "Documentation", "Developer Resources", and "Contact Us". A prominent "Capella" logo is displayed. A descriptive text block explains the Arcadia engineering method, mentioning its focus on functional analysis, complex architecture definition, and early validation, noting its extensibility and customization through viewpoints, and its deployment within Thales across various defense, aerospace, space, transportation, and security business domains.

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