NAVAL GROUP

POWER AT SEA

CAPELLA DAYS 2022

TOWARDS A DIGITAL-NATIVE ENGINEERING AT NAVAL GROUP

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WELCOME!

Thanks for watching the webinar.

Your speakers:

Guillaume Leleu, Naval Group
Corporate methods and tools manager for System Engineering
Research & Development manager for System Engineering

Emmanuel de Château-Thierry, Naval Group
Ship Propulsion System Engineer
MBSE expert
Research & Development Collaborator for System Engineering

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AGENDA

1. Naval Group: who are we?
2. System engineering challenges
3. Moving toward simulation-driven engineering
4. Business use cases & Capella's enhancement (addons)

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WHO ARE WE?

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INTERNATIONAL PLAYER IN NAVAL DEFENCE

50
client navies around the world

16 028
full-time employees equivalents (FTE)

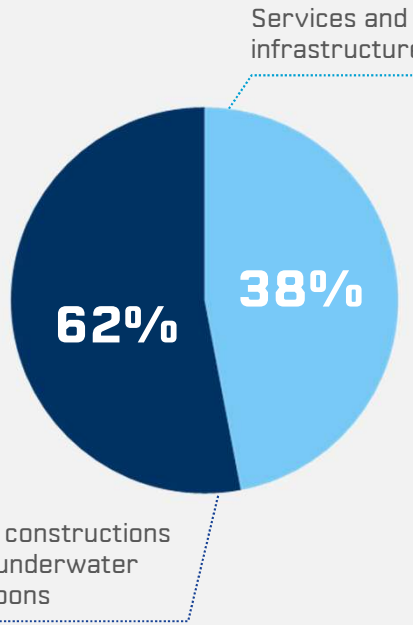
40 000
direct, indirect and induced **jobs**

Global Compact
advanced member since 2014

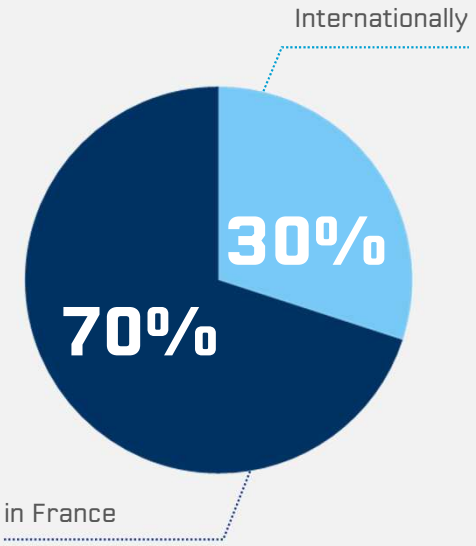
2021 RESULTS

REVENUE	ORDER INTAKE	ORDER BOOK
4,1 Md€	**3,056 Md€**	**14,1 Md€**

Sectoral breakdown
of revenue



Geographic breakdown
of revenue



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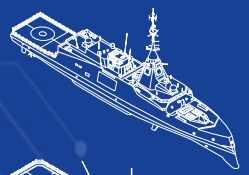
SHIP OFFERS

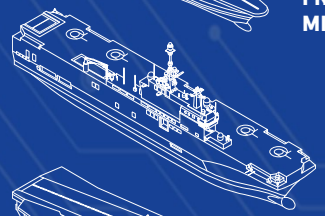
Surface ships

GOWIND® CORVETTE

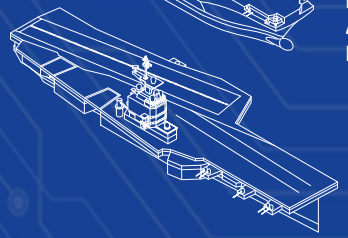


BELH@RRA®

FREMM MULTI-MISSION FRIGATE



MISTRAL-CLASS AMPHIBIOUS HELICOPTER CARRIER



AIRCRAFT CARRIER

SYSTEMS AND EQUIPMENT

- SETIS®
- POLARIS®
- SHIPMASTER®
- SYLVER®

UNDERWATER WEAPONS

- MU90
- CANTO®

Submarines

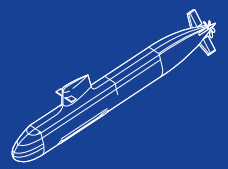
SYSTEMS AND EQUIPMENT

- SUBTICS®
- HOISTING SYSTEMS

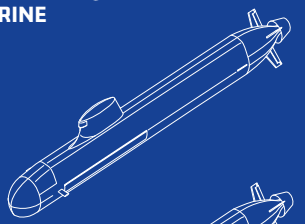
UNDERWATER WEAPONS

- F21 TORPEDO
- CANTO®

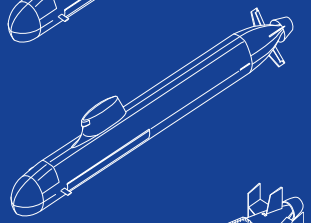
SCORPENE® CONVENTIONAL SUBMARINE



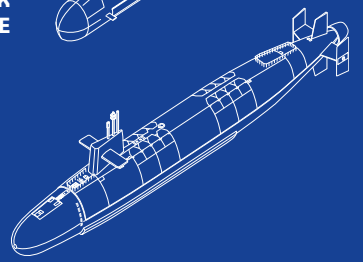
BARRACUDA CONVENTIONAL SUBMARINE



BARRACUDA NUCLEAR ATTACK SUBMARINE



BALLISTIC-MISSILE NUCLEAR SUBMARINE



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SYSTEM ENGINEERING CHALLENGES

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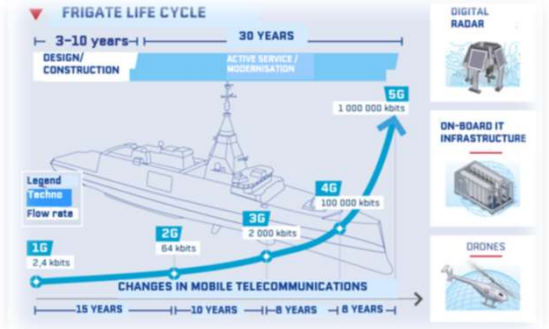
FAST EVOLVING SYSTEMS

- New business capability added, based on pre-defined scheduled but no business capability regression permitted

- New technology introduction (eg. managing the technical debt during the whole warship lifecycle : 45 years and more)

- Increasing interoperability with a constant increase of system automation and autonomous vehicle introduction

SYSTEM OF SYSTEMS AND GUARANTEED SYSTEM RESPONSE



CONTROL OF TECHNOLOGICAL TIME

COLLABORATIVE COMBAT

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MOVING TOWARD SIMULATION-DRIVEN ENGINEERING

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IN A NUTSHELL
SIMULATION-DRIVEN ENGINEERING

- Requirements-based inputs → documents-based outputs as « usual » engineering techniques can not keep up with the (system) evolution pace :
  - National and International collaborative engineering
  - Distributed factories
  - On-shore, off-shore, at-factory trials…

We want to progressivly shift to Simulation-Driven Engineering to:

- Lower the technical risks to discover performance issues too late in the construction process.
- Optimise the end-product and lower its environmental footprints: less raw materials, less energy consumptions during the overall product lifecycle.

Enable short-engineering loop between multiple actors based on outputs from simulated (system) behaviors

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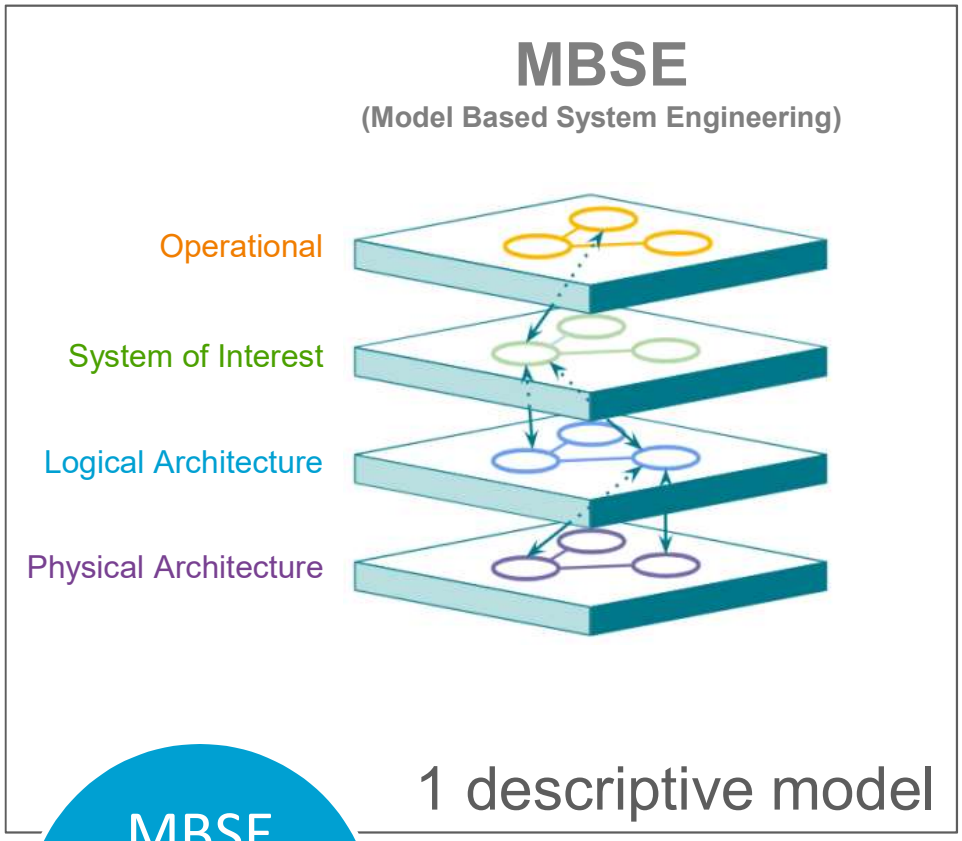
A DESCRIPTIVE MODEL-DRIVEN ENGINEERING



MBSE

Source of truth

1 frame to describe the system : the needs (operational and system views), the solution (logical and physical views).

- Shared with all system engineers
- **Describe the system for a mutual understanding of all involved parties**
- **Single data source as an input for all engineering domain specialists** (functional, dysfunctional) to understand the system's specification and **PURPOSE**

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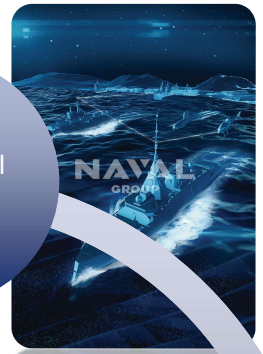
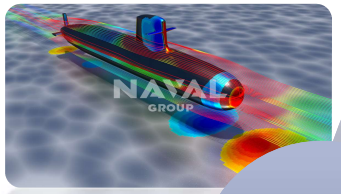
…TO SIMULATION-DRIVEN ENGINEERING

USING A SINGLE SOURCE OF TRUTH AND INTEROP/PLATFORMS OPEN STANDARDS



- Overall performance sim
- Battlelab for sim & training
- SoS optimisation
- Product line & variants sim
- Mission package and variants sim

Operational Simulation



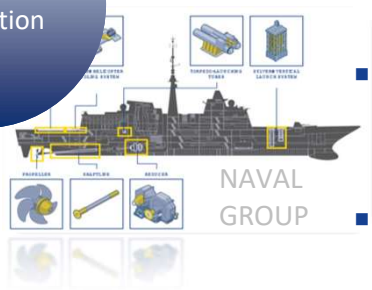
- CFD (Mechanics, Fluids, etc)
- Advanced acoustic/magnetic/flow dynamics science and computation

Multi-Physics simulation

MBSE

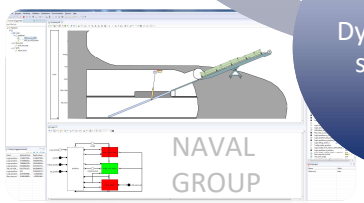
Source of truth

Functional Simulation



- Early-validation of systems design
- SiL, HiL early integration for early validation
- Recursive (top-down or bottom-up) engineering eased by progressive V&V

Loosely-coupled relationship



Dysfunctional simulation

- Decision helper for critical and safety related systems
- FMEA, root cause analysis, safety assessment, etc

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USING A SINGLE SOURCE OF TRUTH AND INTEROP/PLATFORMS OPEN STANDARDS

DONE in 2021

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Operational Simulation

Characteristics

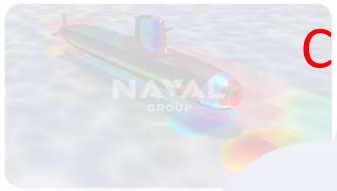
MBSE

Source of truth

Multi-Physics simulation

Functional Simulation

Dysfunctional simulation



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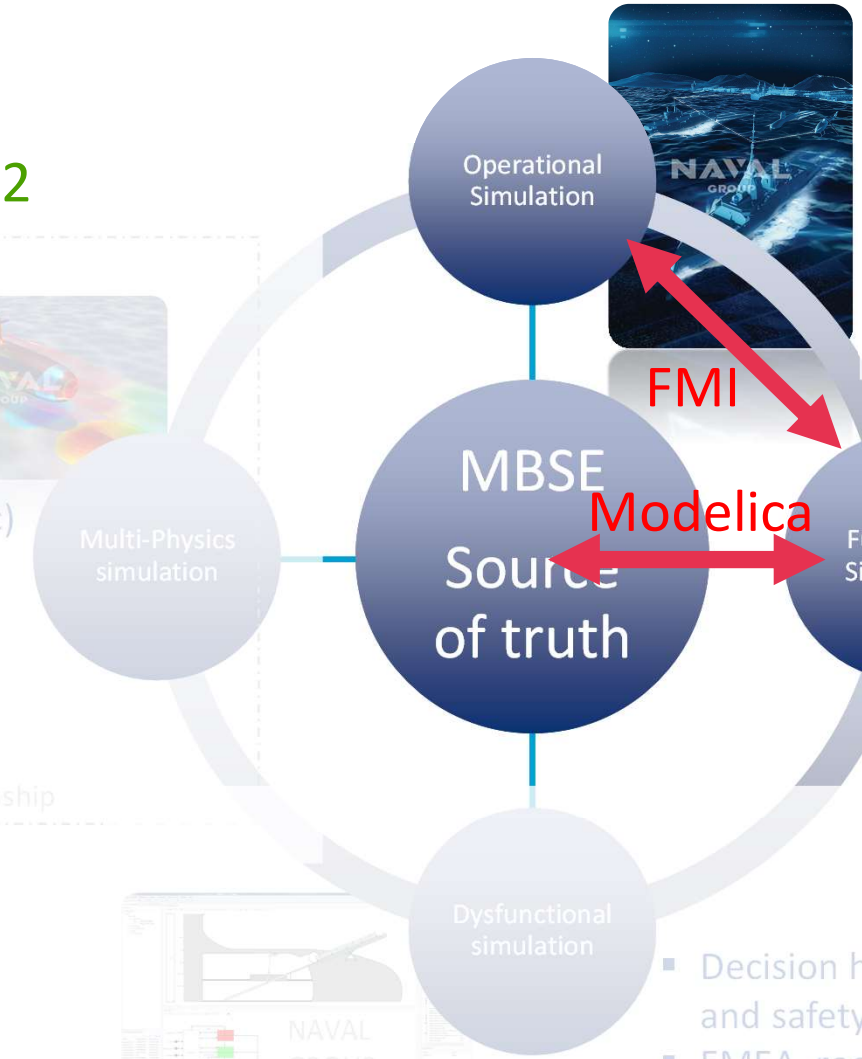
USING A SINGLE SOURCE OF TRUTH AND INTEROP/PLATFORMS OPEN STANDARDS

DONE in 2021/2022



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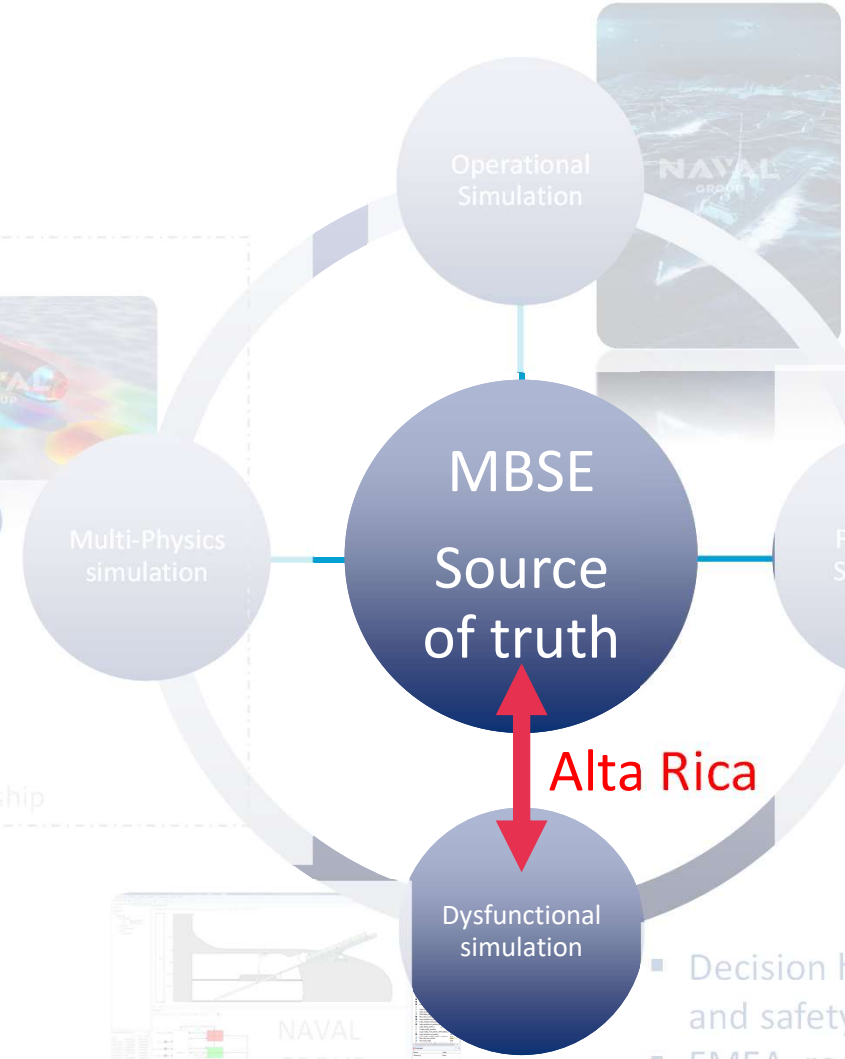
…TO SIMULATION-DRIVEN ENGINEERING

USING A SINGLE SOURCE OF TRUTH AND INTEROP/PLATFORMS OPEN STANDARDS

In progress



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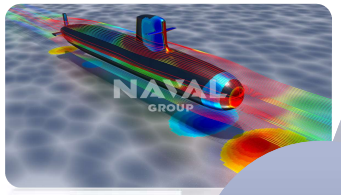
USING A SINGLE SOURCE OF TRUTH AND INTEROP/PLATFORMS OPEN STANDARDS

In progress

CO SIMULATION PLATFORM
FMI/FMU



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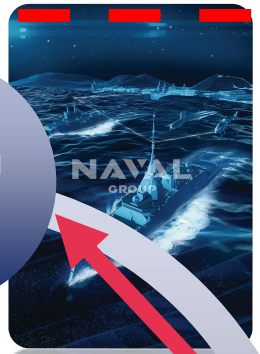

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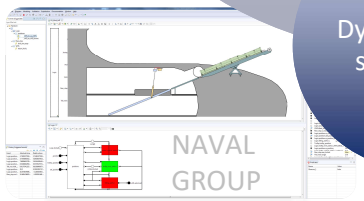

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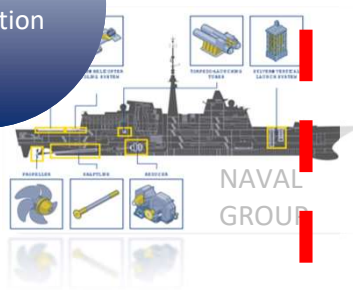

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MBSE CAPELLA

Capella is deployed in the Research and Development organisation.

WHY? Fast deployment and easy learning-curve:

- ✓ It embeds a step by step method (Arcadia).
- ✓ It embeds productivity tools (for the end-user) focussing on designing a system (eg. hides the underlying conceptual/data model complexity).
- ✓ It is based on an Open Architecture & Technology (EPL licence)
- ✓ Available to anyone at an affordable cost (key criteria for massive adoption)
- ✓ It is widely spread across the French Defence Technological and Industrial Base

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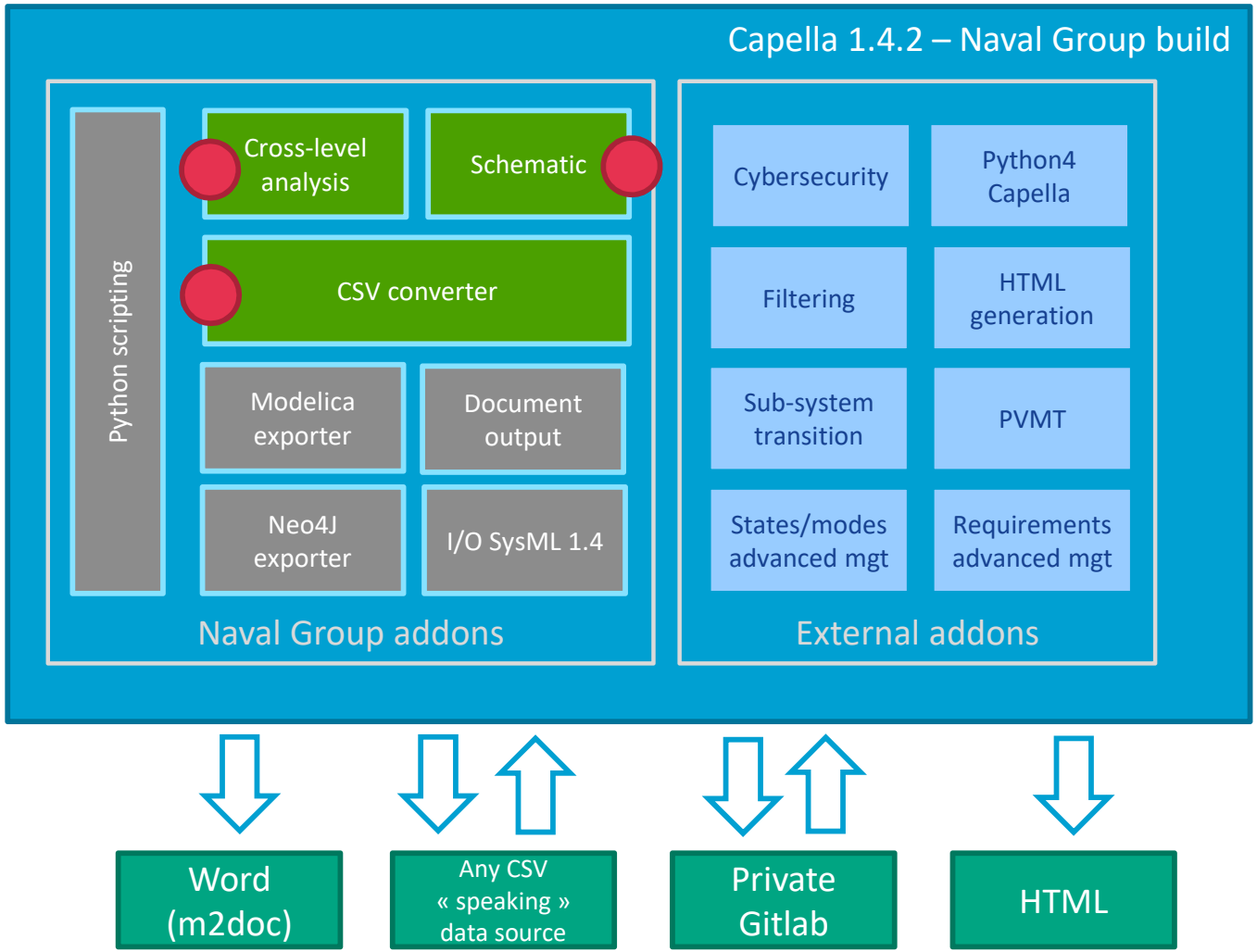
CAPELLA 1.4.2
DEPLOYED AS « ALL INCLUSIVE BUNDLE»



Today's talk

Available for download on Labs4Capella

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BUSINESS USE CASES & CAPELLA'S ENHANCEMENT (ADDONS)

USE CASE #1
INTEROPERABILITY AND MORE

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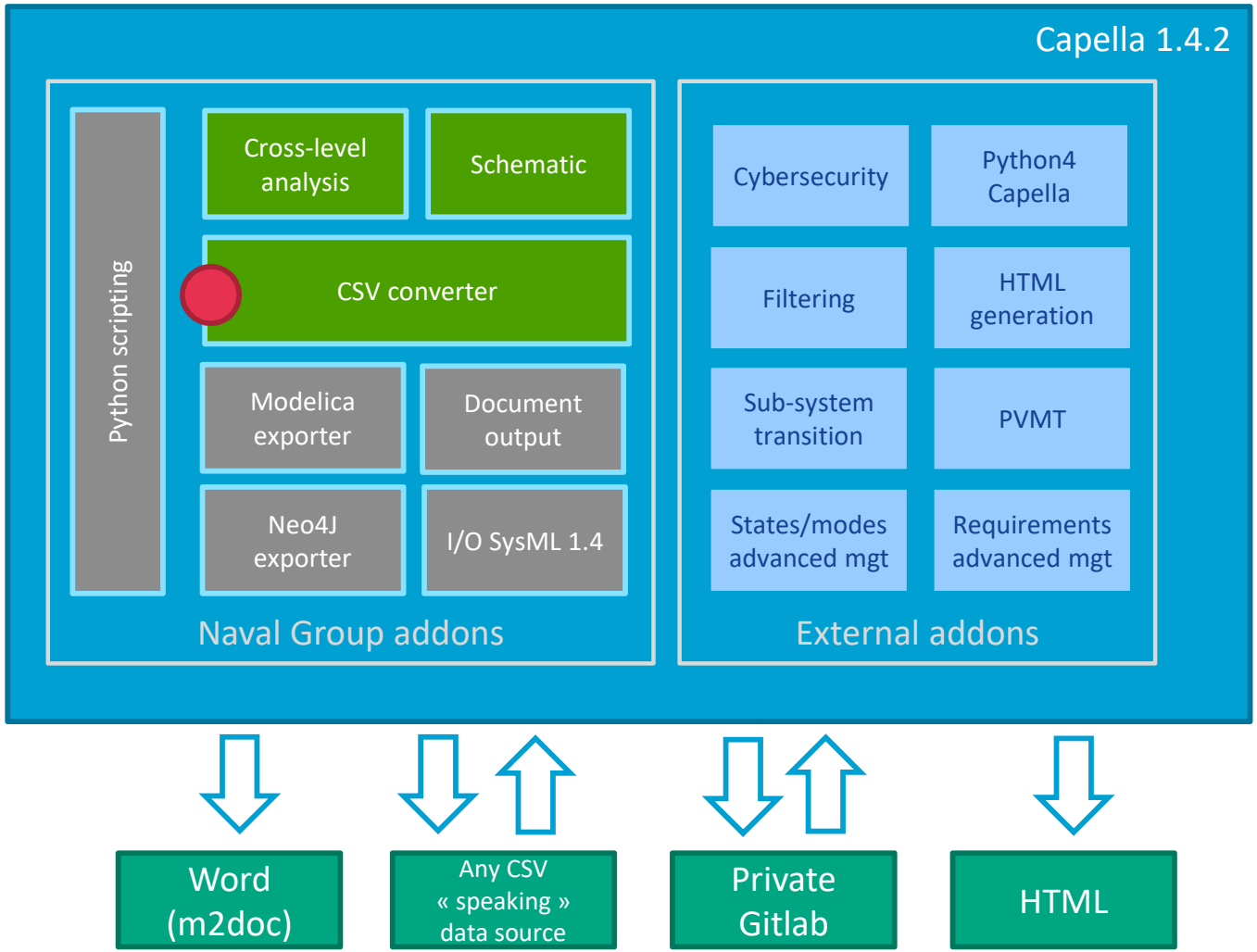
CSV CONVERTER



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INTEROPERABILITY WITH OTHER SYSTEMS
CSV ADDON → THE SWISS ARMY KNIFE

- #1.1: Import existing data assets to prepare and accelerate engineering studies
- #1.2: Enable collaborative work with partners within consortium
- #1.3: Import and export requirements
- #1.4: Import and export any data from any systems or modelers inc simulation data
- #1.5: Translate all model elements to create a new language-specific model
- #1.6: Extend the « Mass Editing View » capabilities with external automation
- #1.7: Allow 3rd parties meta-model basic interoperability (NAF, TOGAF, SysML, etc)

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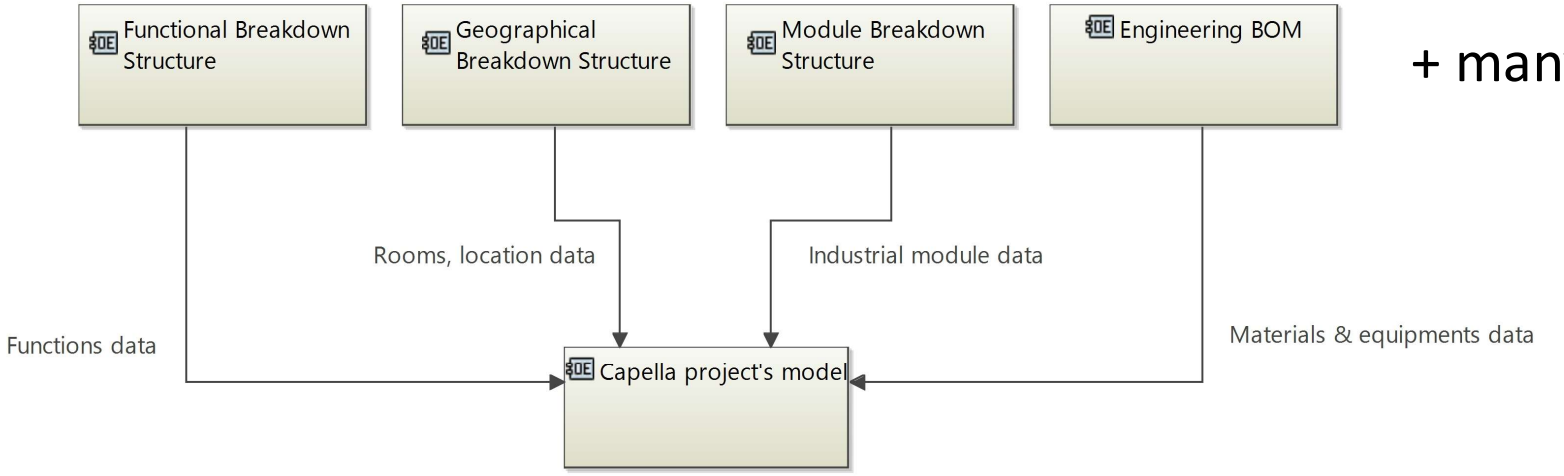
USE CASE #1: IMPORT EXISTING DATA ASSETS TO PREPARE AND ACCELERATE ENGINEERING STUDIES



- After a few hours of practicing, we discovered the lack of Capella's capabilities to import and export data. It was clearly a show stopper for rolling it out as we need:
  - to import (plenty of) existing data from our existings assets to accelerate the engineering phases as well
  - to export data to our PLM environment to allow transitioning to basic and/or detailed design phase.

We decided to develop and roll-out a *generic* CSV connector I/O data from/to Capella.

Note: as we now manage Capella assets, we are moving toward Capella's library management within our private Gitlab and less using the CSV addon

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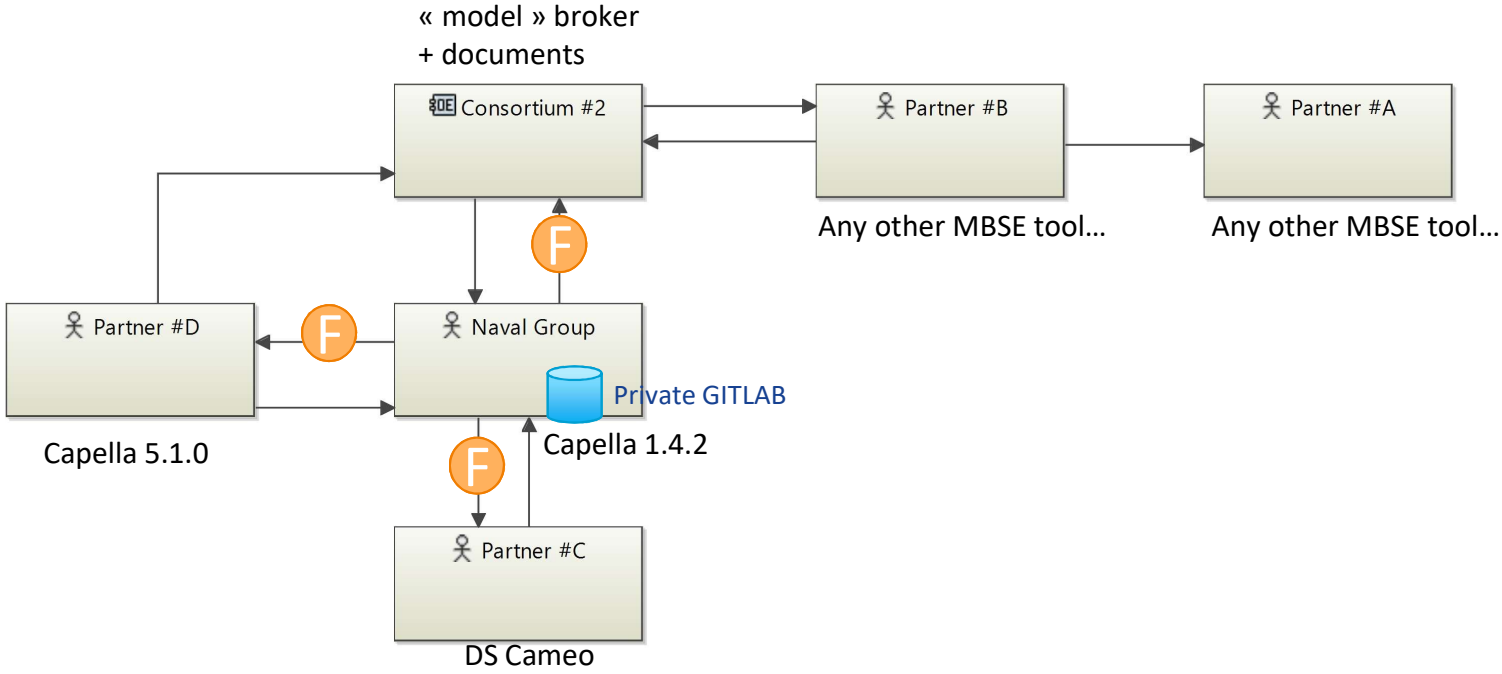
USE CASE #2: ENABLE COLLABORATIVE WORK WITH PARTNERS WITHIN CONSORTIUM(S)

CONTEXT

- No OBEO Team4Capella available
- No common GITLAB available
- Heterogeneous Capella's version landscape
- 3rd parties MBSE
- Partial model exchange (for industrial, confidentiality, etc reasons) required



- Import and export « neutral-ised » data (= technology independant) is a best and cost effective way to still collaborate, however with (human) data management effort

F Identifying non exportable data is done directly within Capella with a property and then filtered out after the CSV export within an external tool (MS Excel, LibreOffice, database engine, etc) – or with the help of Python4Capella

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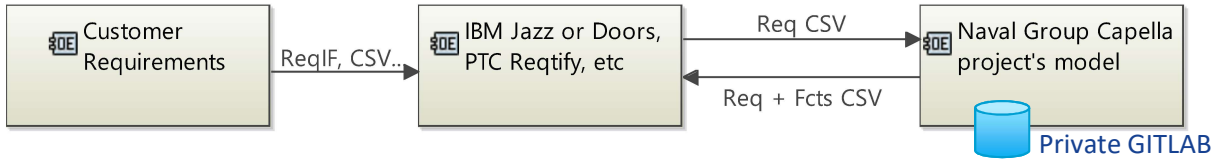
USE CASE #3: IMPORT AND EXPORT REQUIREMENTS

CONTEXT

- No use of ReqIF format due to its own limitations, heavy efforts to properly export from other tools, etc
- No use of « requirements » object's type as it did not fit with our ways of working (too specialised between UR, SR, NFR and level-restricted : OA, SYS, etc)

- **Use of « out of the box » property values to manage requirements as well as their dependencies across layers, assigned to any kind of model's object type.**



- Import and export « neutral-ised » data (= requirement format independant and software settings/customizing independant) with any requirement software tool
- Still able to able to manage traceability, across layers with Capella's out of the box tooling inc in document generation using M2DOC as well as HTML generation
- Python4Capella is great to export formatted (structured) data for ICL (Interface Control List) information, etc.

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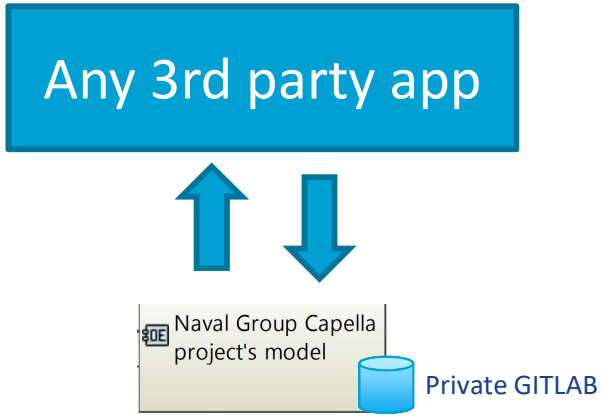
USE CASE #4: IMPORT AND EXPORT ANY DATA FROM ANY SYSTEMS OR MODELERS INC SIMULATION DATA

CONTEXT

- Exchange data with any 3rd party system requiring architecture's data, especially characteristics (for simulators) or for wider system engineering dataset analysis (eg consolidated Business Intelligence)

- **Use of « out of the box » property values and/or PVMT to populate characteristics from 3rd party systems or to send them to 3rd party systems**



- Import and export « neutral-ised » data (= format independant and software settings/customizing independant) with any software tool by using key/value properties
- Still requires a « proxy » or « mediator » in between the 3rd party app and Capella to extract sensible data from the CSV and most often convert them to the right data type format → scientific tools require to be filled in with appropriate data's type: float, integer, etc

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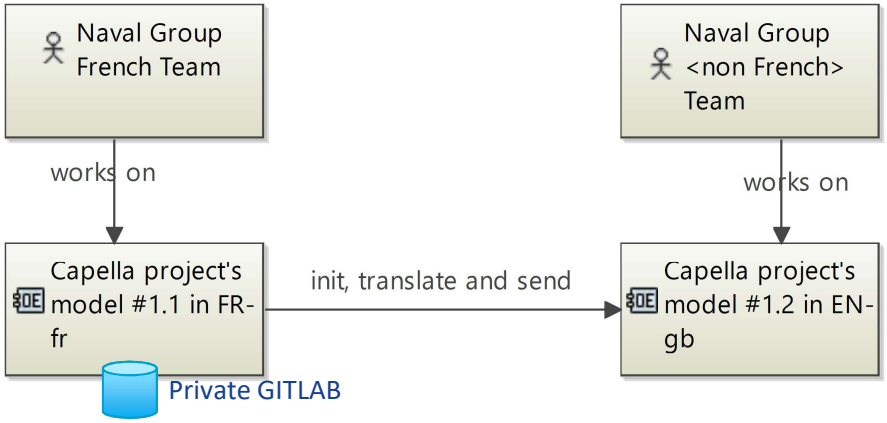
USE CASE #5: TRANSLATE ALL MODEL ELEMENTS TO CREATE A NEW LANGUAGE-SPECIFIC MODEL

CONTEXT

- Exchange a pre-populated model from our French engineering team to another non French speaking engineering team
- Capella as a tool and its underlying data model does not support multi lingual features « out of the box »



- Export the French only Capella's project using CSV
- Translate each object's description, name, etc using a mapping sheet/table in your preferred tool (MS Excel, LibreOffice, etc) and regenerated a CSV by only replacing the appropriate text columns (name, description, etc) and keep all other data untouched
- Copy the existing Capella's model (FR) to a new one (EN) and simply import the CSV files. Job done the entire Capella's model is updated in the new language.

Tip: Automated translation process is possible (python script, etc) to avoid human in the loop (→ triggered by CSV export on client side or even possibly in the gitlab), as well as using directly in the model additional properties (key/value) for additional languages (and avoid to use an intermediate mapping table/sheet)

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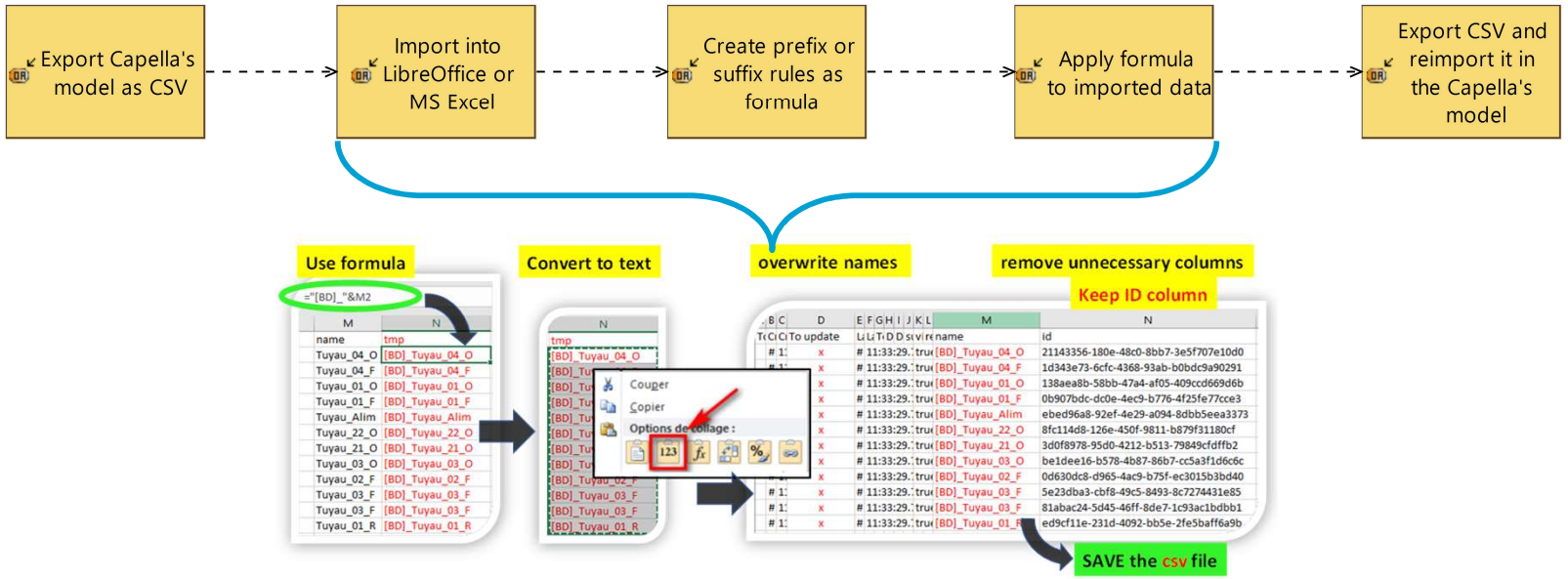
USE CASE #6 : EXTEND THE « MASS EDITING VIEW » CAPABILITIES WITH EXTERNAL AUTOMATION

CONTEXT

- The out of the box « Mass Editing View » is very useful however for « rule-based » mass edition , it is not ideal for large dataset as it implies manual edition cell by cell



DEMO

- Manual process but with data transformation automation for small to very large dataset. Thanks to external spreadsheet engine capabilities to filter data based on conditions easy-ing to apply rules on relevant data…

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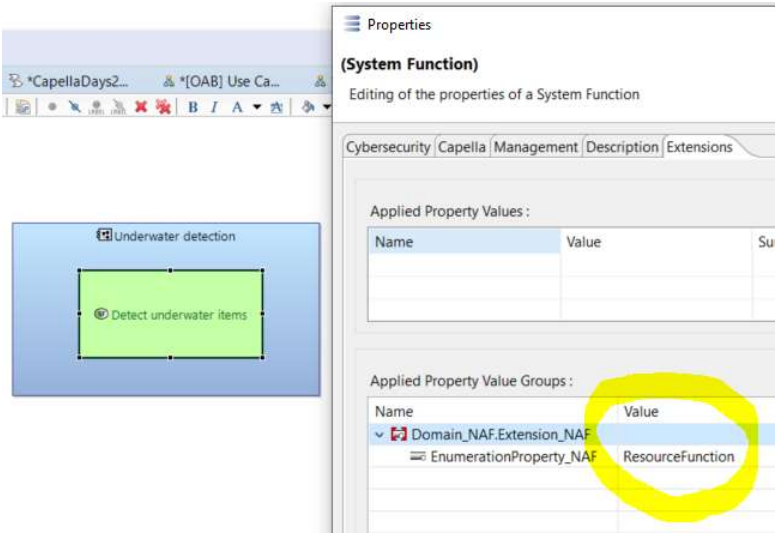
USE CASE #7: ALLOW 3RD PARTIES META-MODEL BASIC INTEROPERABILITY (NAF, TOGAF, SYSML, ETC)

CONTEXT

- NATO architecture framework (NAF) is widely used in the Defense Industry by customers, reminder : main goal is to plan acquisition of technical capabilities (eg naval, air, ground units, …) to fulfill operational capability's needs over time.
- NAF is not a system or system of systems design/conception framework for industrials. Arcadia (and others) better fits to elaborate the solution (system, logical, physical levels).

→Mapping NAF or other end-user capability orientated frameworks needs to be performed with "industrial-like" conception frameworks.



- Create a PVMT domain with all "concepts" you want to map to Capella's object
- Assign the NAF concept to Capella's element
- Export is as CSV and then you have the relationship NAF/arcadia object's type at the element level
- Process it as you wish outside of Capella…

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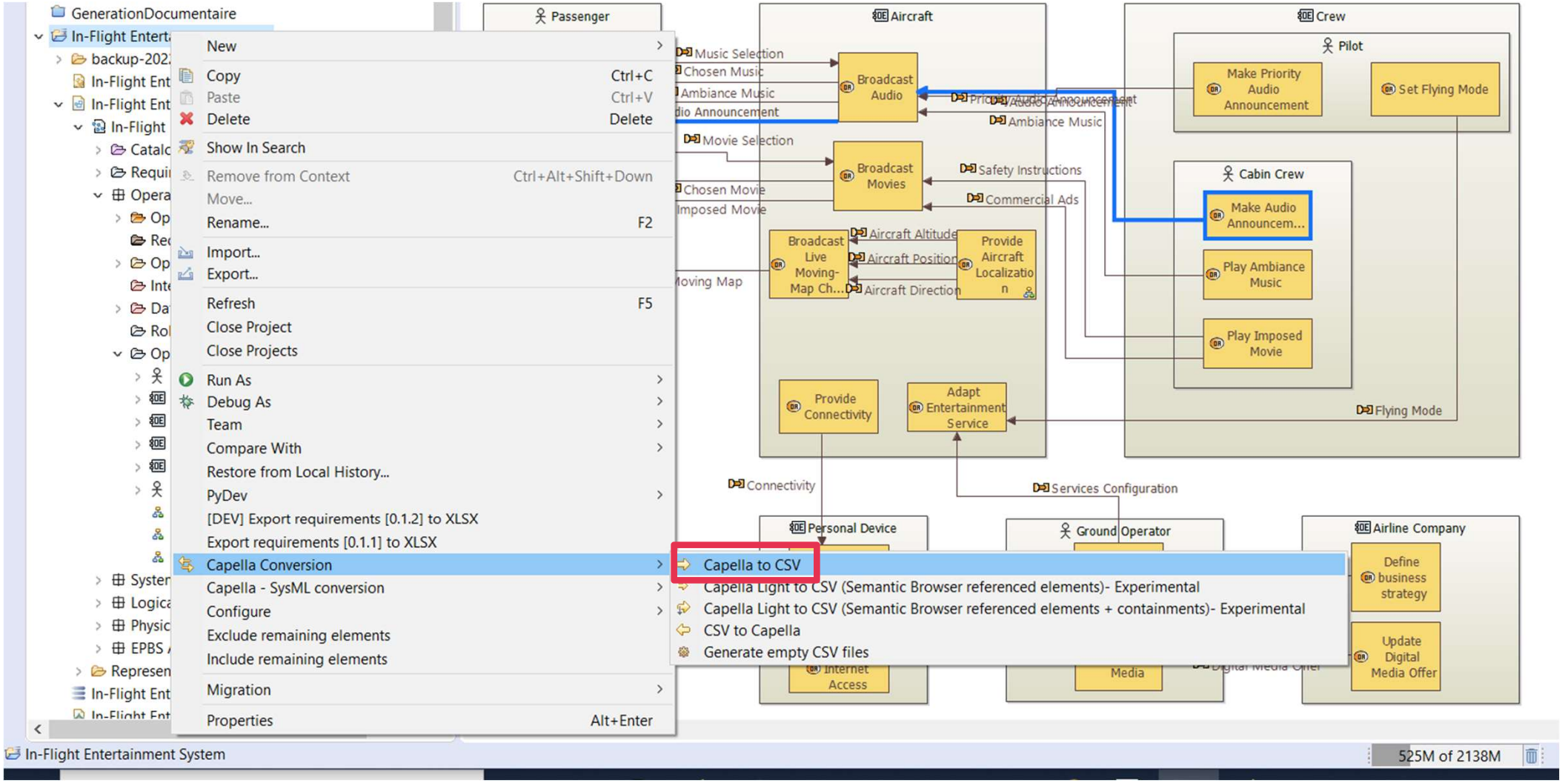
DEMO: HOW TO EXPORT

> Open up your model, then right-click on the projet and select Capella Conversion



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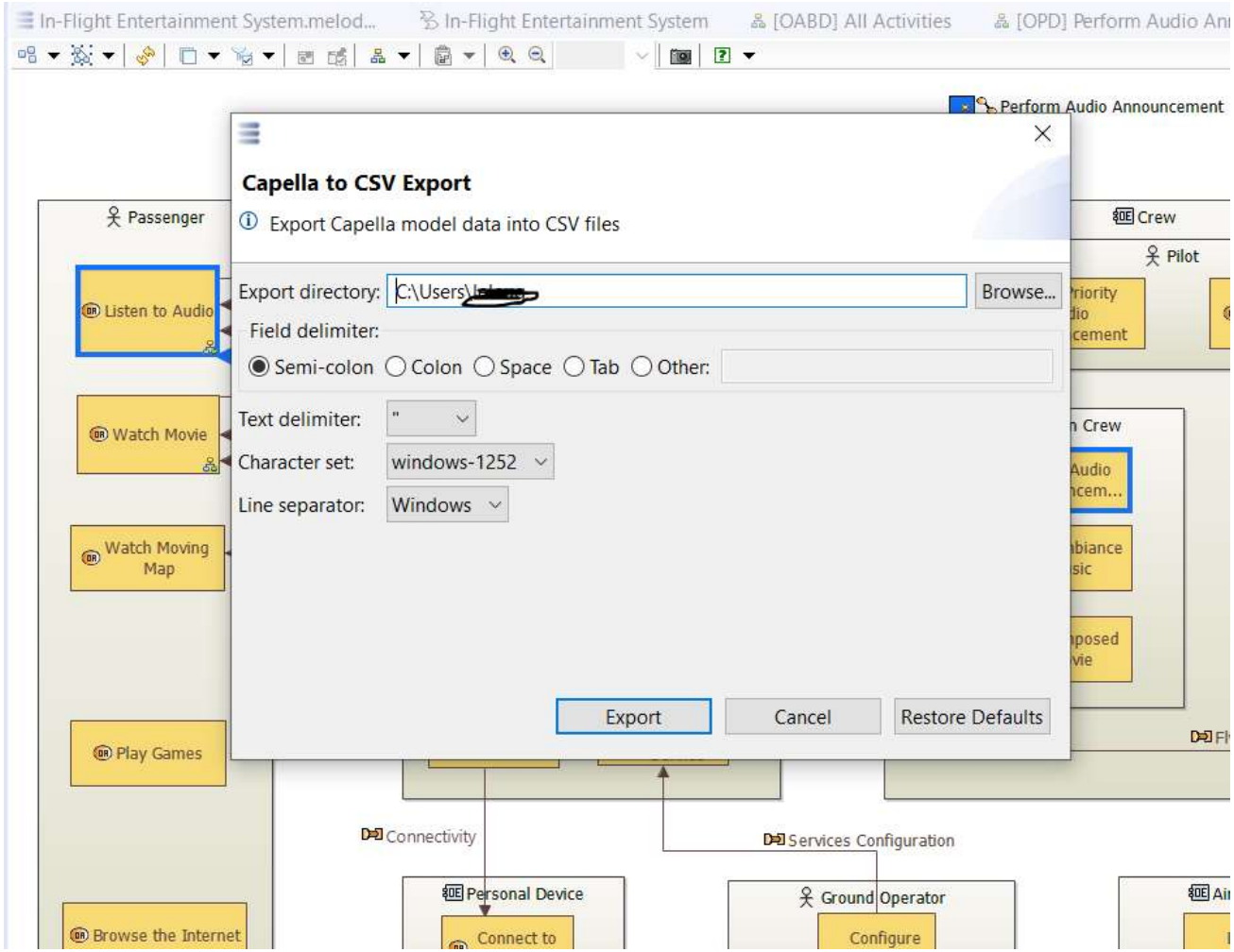
DEMO: EXPORT PROPERTIES

> Select the export/import options and target/source directory



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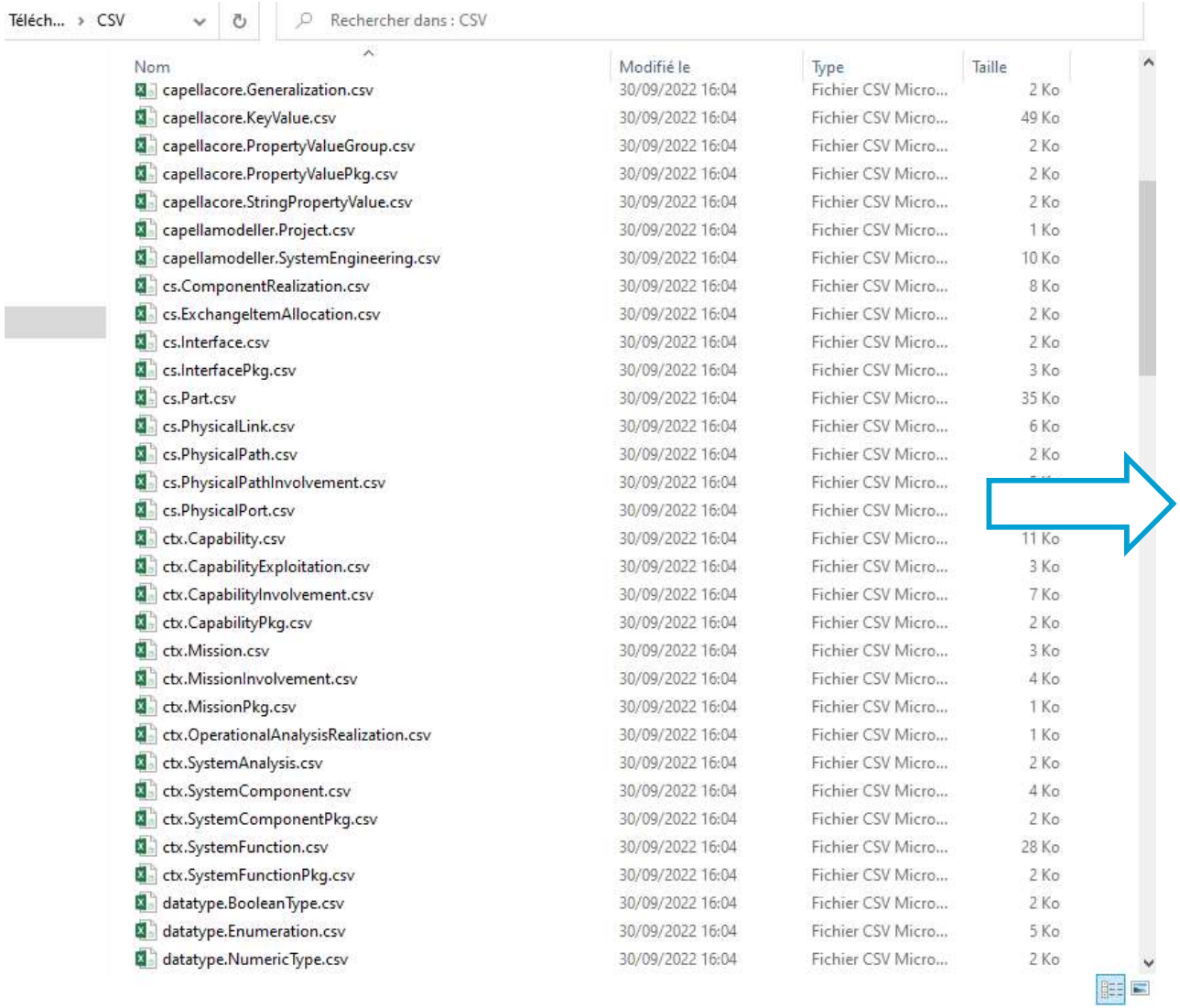
DEMO: EXPORT DONE



One CSV file is generated per Capella's object type

> Not user-friendly but it is a full data model export

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DEMO: A CSV FILE STRUCTURE

name	description	id	visibleInLM	ownedAbstra	ownedAbstra	ownedPrope	ownedCapabilityInvolvements	ownedPropertyValueGroups	includes	namingRules	ownedFunctionalCha
Provide Audio and Video Intercommunication Means		291fb362-9ae	true	[d44091f2-90b5-4b15-97b6-abf3f612f5d6			[329c0df9-a854-49ab-9404-bf2047a0ebf0, f8e27041-27b6-41c9-be91-a8d59884a141, e9b7c835-6216-4e1c				[dd56a4c7-8304-4471-
Provide Video Entertainment Services	<p>	839ba873-84	true	[3223678f-d8	[029014ef-b01e-4e2d-ac30		[c2c2235a-8a6a-4058-82b3-034c860ff867, c499a1c8-1312-4509-b54b-2c1004edd7d1]				[e00b45ce-330b-4b19
Provide Video Gaming Services	[Wikipedia]	b3a96943-f9e	true		[062b766d-1568-45b3-a802		[29d27502-5da6-4eda-992b-30511328ea42, 538db62a-46bd-49ea-bbf3-e0125449622c]				
Provide Wi-Fi Connectivity Service	<p>	67bacc43-806	true				[5aa0fd88-e13e-46cb-a9e7-9dc048384470, de4a9829-7f09-466b-b4cd-e35e08f455ef]				
Provide Satellite and Internal Telephony Services	[Wikipedia]	43207098-1d8	true				[9e78649f-cb2a-43d0-b66a-e8259faa96f8, 91554616-d8df-4609-87c6-3c5244d52b42, c997d97b-3354-4f65-a818-df7f23494e90]				
Provide Moving-Map Services	[Wikipedia]	4e6fa11e-933	true				[b5e2ccdb-fd59-45fa-82df-d6befe26e3f2, 83ebcfb9-5910-4953-bc1f-c0845b9eba9e, 2554815f-2af9-4e3a-a799-8b07586f0f2c]				
Provide Audio Entertainment Services	<p>	4cfe1222-e1e	true		[e1c86c2a-25af-4a30-b3c6-		[9a14f5a5-19f6-402a-892e-cb2157516afc, 918dc8ab-dbe2-4eba-b29a-a44b45445013]				
Provide Personal Device Connectivity		9a942752-caa	true				[9f6b68c8-a52f-4519-9df7-805d919e84d3, 2c820cf9-021e-4da6-ab26-293256593868]				
Provide Testing Interface		1adec5b0-a1	true				[0ee8aaed-8169-42cf-b3d0-ad5a85073fc3, 6bf47529-0871-4192-a17f-3e58e23dee2c, 23a88d41-9bb3-413e-ba74-c6f5697e4c0b]				
Provide Configuration Means		a643f8af-010	true				[5469be78-c432-4ac4-860d-b1776203db6d, c44d4096-d1ed-4b81-b3d7-d5c235ce3859, 2053a39e-ec0e-4cd1-a703-25d69db0fc95				
Update Entertainment Offer		32ff49c3-04b	true				[3052189a-ac66-4e3f-9d14-09cf9df749c8, be87b851-9c85-4426-a431-819434d768e1]				
Provide Access Management Control		74e6e35e-b1	true	[f009fd01-1759-4fb2-9cbc-8d420846e2b9			[01f3cd77-b7cb-4b0d-a42e-93f3f226ba3c, 377a8da4-97cb-4f13-a534-906a394	[a5484293-196f-4bfa-bd4d-ada478a0e48d]			
Integrate Aircraft Constraints		5acd248a-39	true	[0d218f22-8c03-4d9b-95c7-d4a54ea4373			[2dbb068b-75d7-4016-ad0d-64a230f055a1, fd5f660b-d23d-45ca-b8fa-452f750cc882]				

A row contains an element (eg object type) and the columns are properties.

Caution: relational properties are embedded within a cell as a « regular » Array (eg [id#1, id#2, id#3,…]). Ids are the unique identifiers of the corresponding object, found in its corresponding CSV file (by object type).

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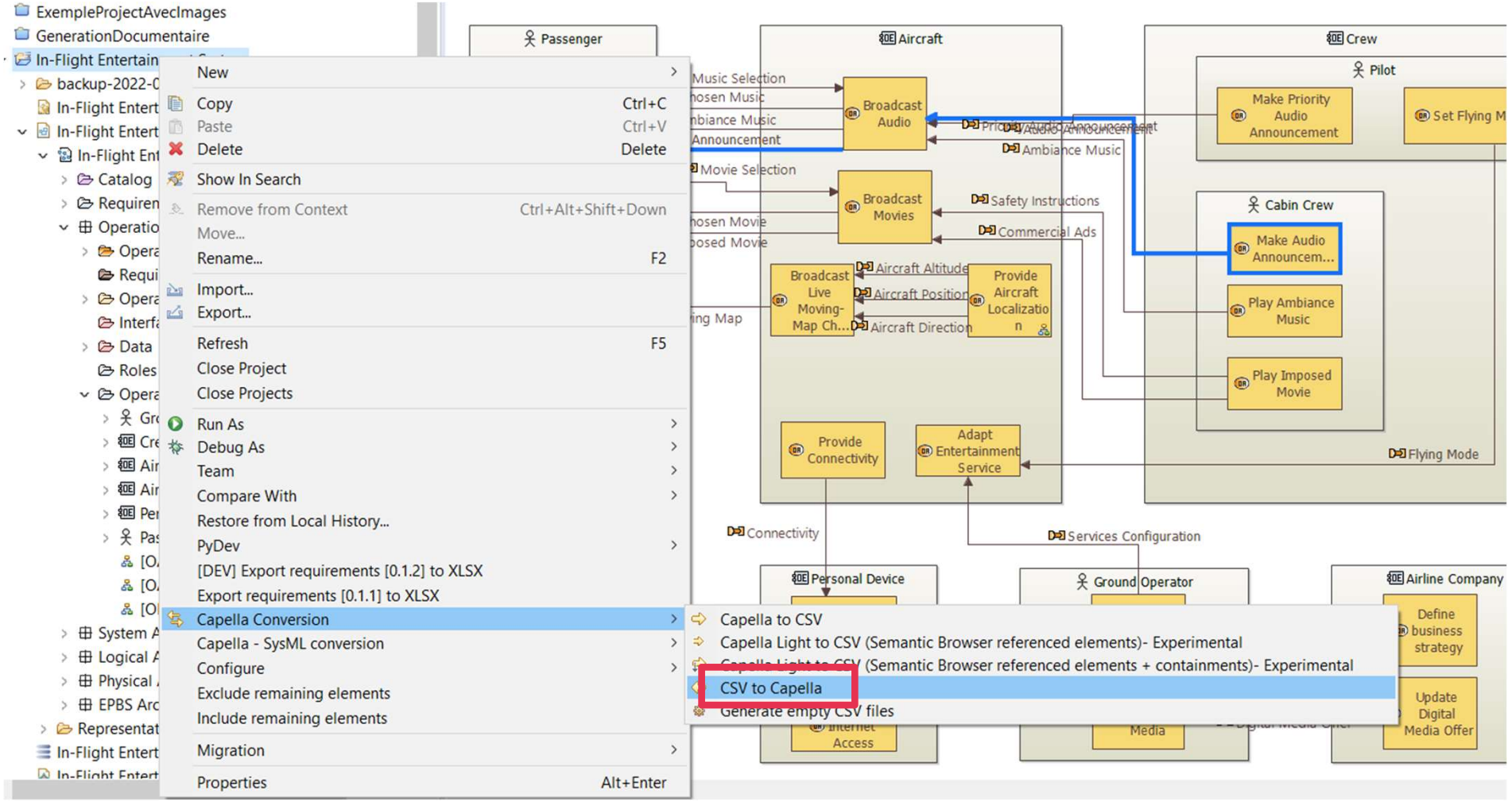
DEMO: HOW TO IMPORT

DEMO IMPORT LOGICAL COMPONENTS

> Open up your model, then right-click on the projet and select Capella Conversion



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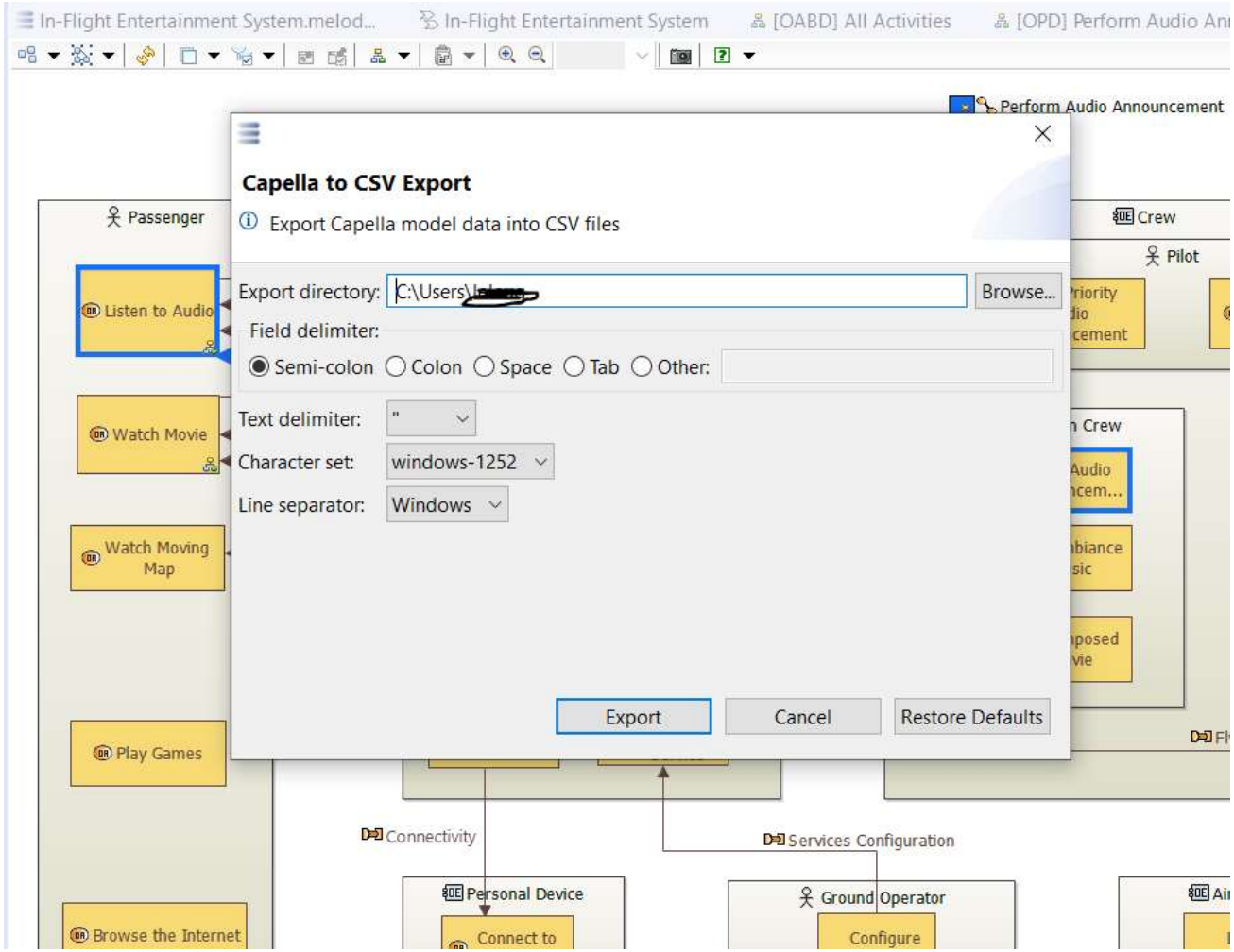
DEMO: IMPORT PROPERTIES

> Select the export/import options and target/source directory



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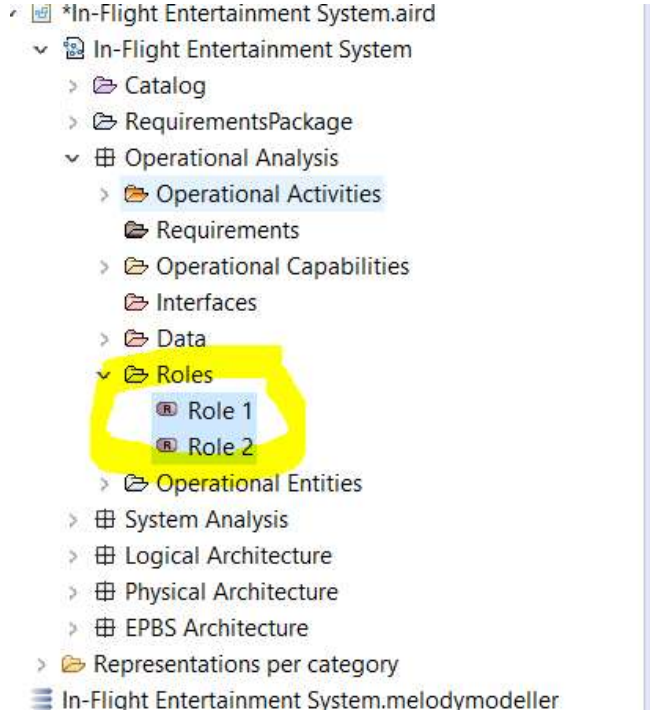
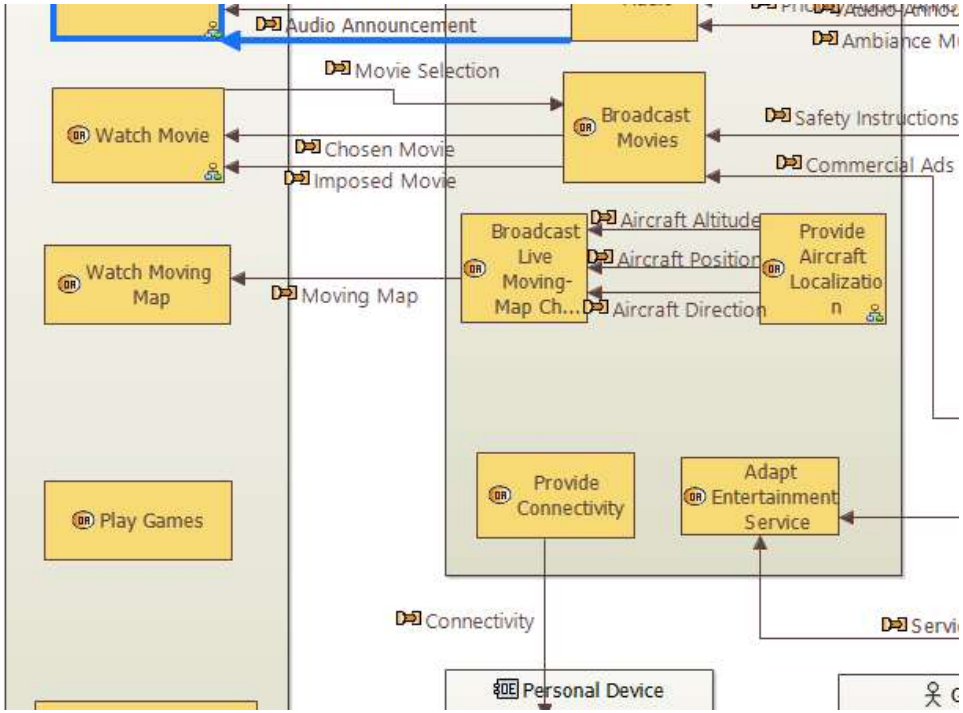
DEMO: IMPORT DONE!





Please read the documentation as the import is flexible and several options exist.

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CSV ADDON LESSONS LEARNED

- Very powerful as it solves many business and interoperability issues, even at the meta-model level (eg NAF ←→ Arcadia).

- Not friendly-enough for « business user », we had to develop an Excel spreadsheet with VBA macros to automate the « fill-in » process of the CSV files for the data import

CSV Export is now reserved for advanced users for specific needs. Thanks to Python4Capella we now tend to develop ad-hoc scripts for exporting on-purpose data : Interface Control List, Requirements ←→ System, System's (simulation) characteristics, etc.

For import, it is the best productivity tool we have.

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BUSINESS USE CASES & CAPELLA'S ENHANCEMENT (ADDONS)

USE CASE #2
RECONCILE FIELD-SPECIALIST SCHEMAS AND MBSE

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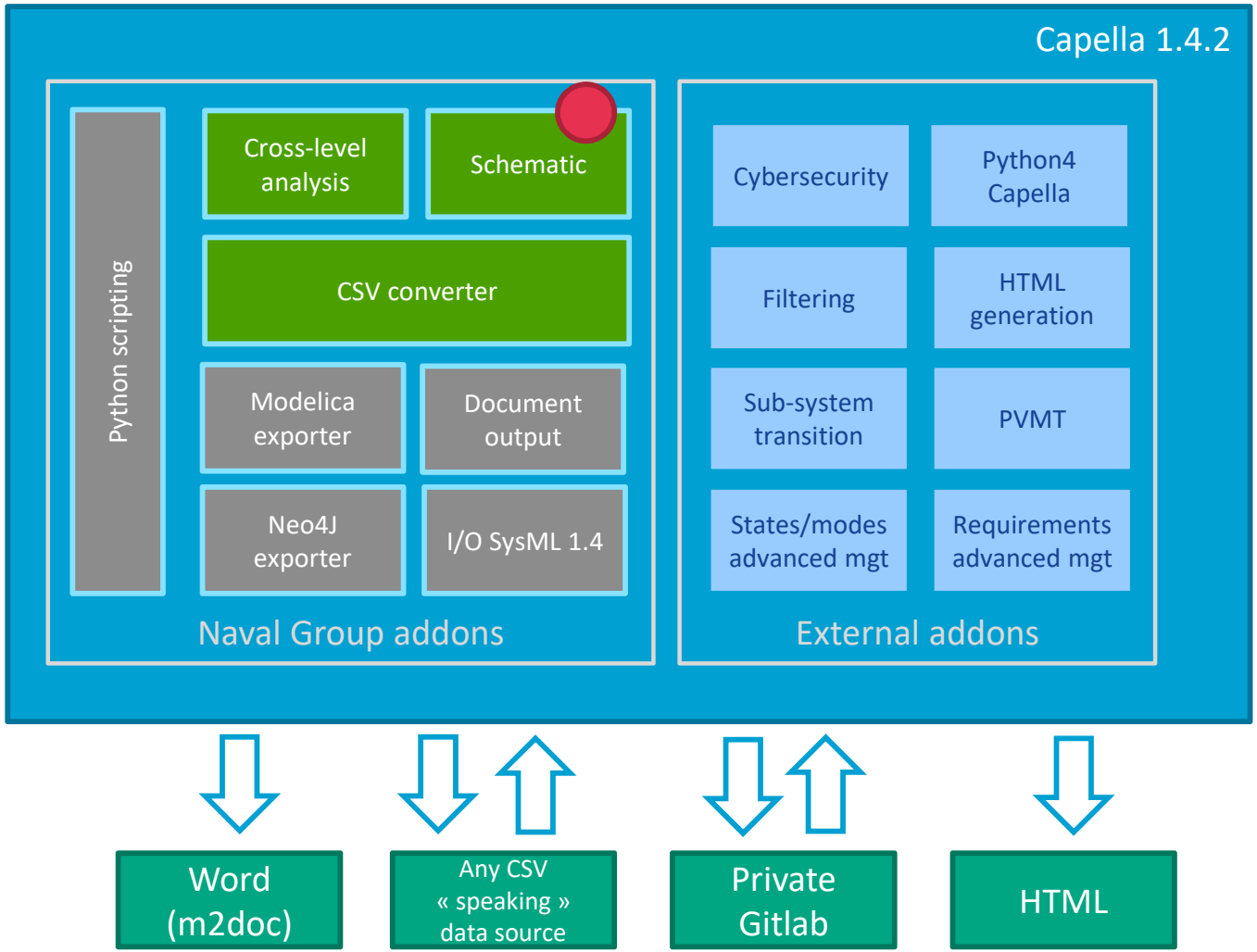
SCHEMATIC ADDON



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USE CASE #2 – MIND THE GAP BETWEEN P&ID, PFD AND MBSE

- Delivering P&ID (Piping and Instrumentation Diagram) and PFD (Process Flow Diagram) is the usual way of describing the architecture (how functions are realised by an equipment located in a geographical location) of a cyber physical system (electric, mechanical, hydraulic, hvac, etc). It is a common practice which is also driven by international norms and regulations and as well asked by regulator authoritees to verify system design conformance to legal rules.

- Physical layer in Capella does address the same purpose, leading to duplicate the effort to describe the physical architecture

We decided to develop for high level design phase the capability to Capella to generate the PIDs/PFD diagrammes based on the « usual » MBSE block view.

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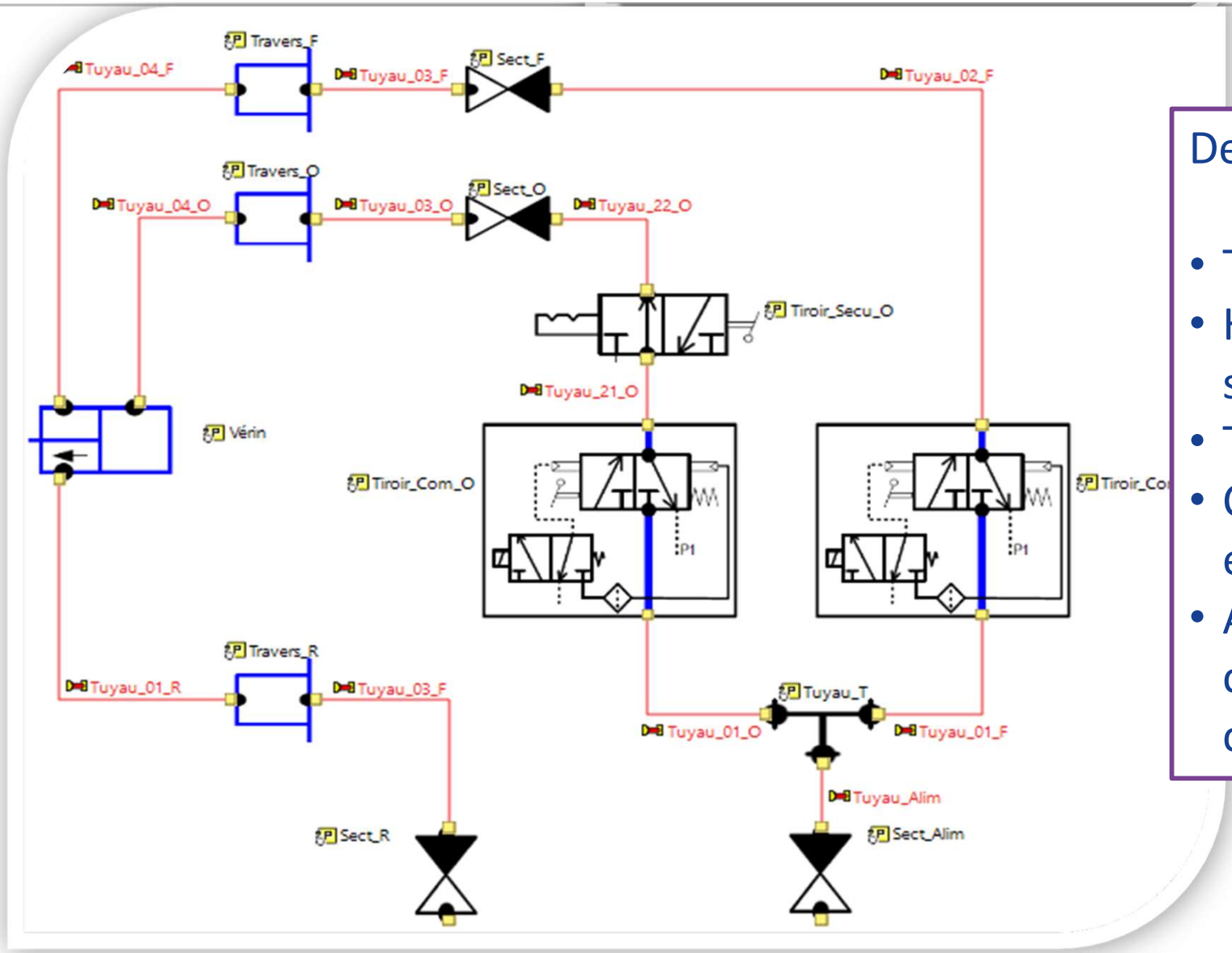
AN EXAMPLE FOR A HYDRAULIC SYSTEM (PID/PFD)



Describes:

- The «flow of material »
- How to control the system and with what
- The safety mechanisms
- Connections between equipements
- Additional characteristics such as capacity, location, etc

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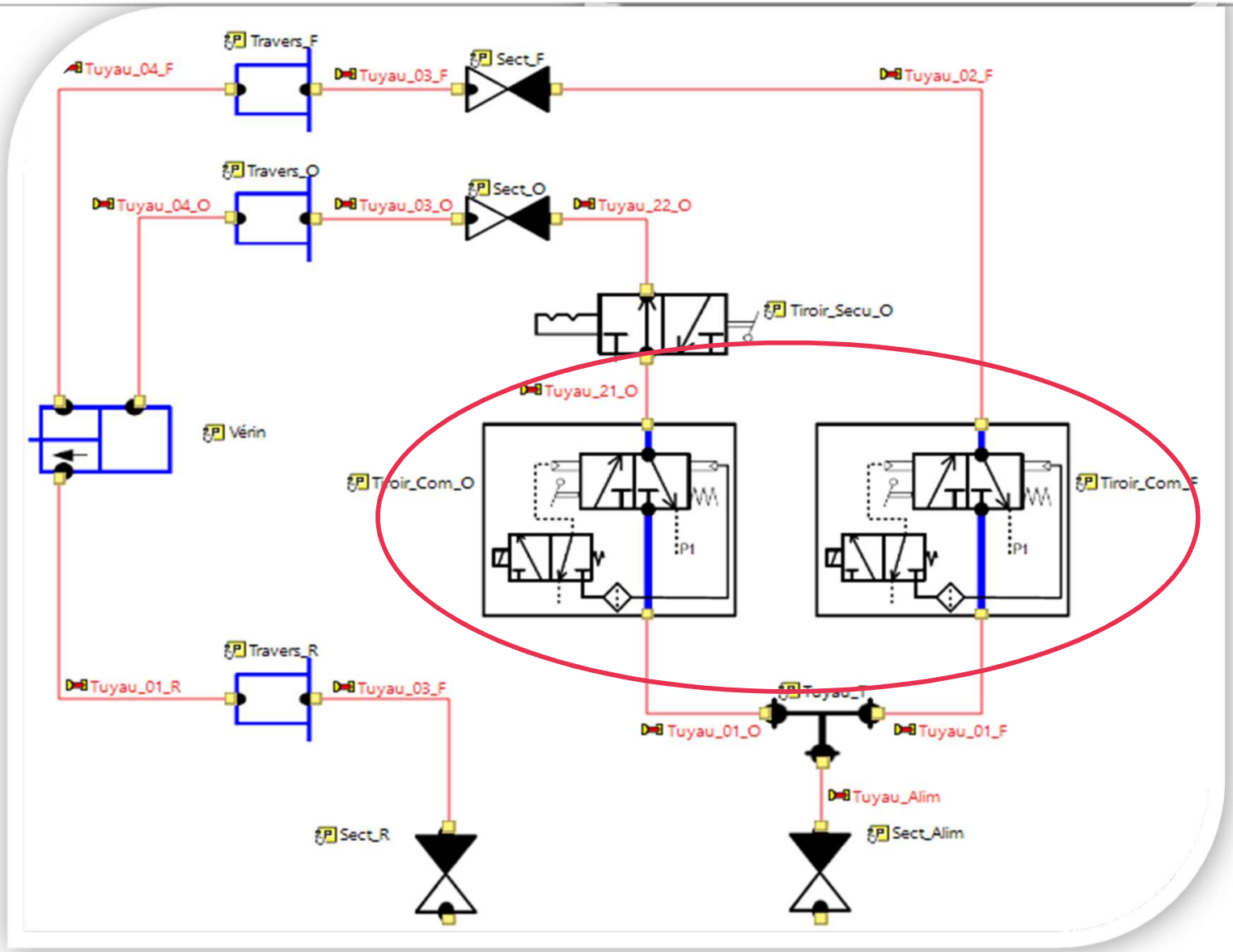
AN EXAMPLE FOR A HYDRAULIC SYSTEM (PID/PFD) – FOR DUMMY



=

To (remotely operate) CONTROL IN/OUT the hydraulic cylinder

FUNCTION

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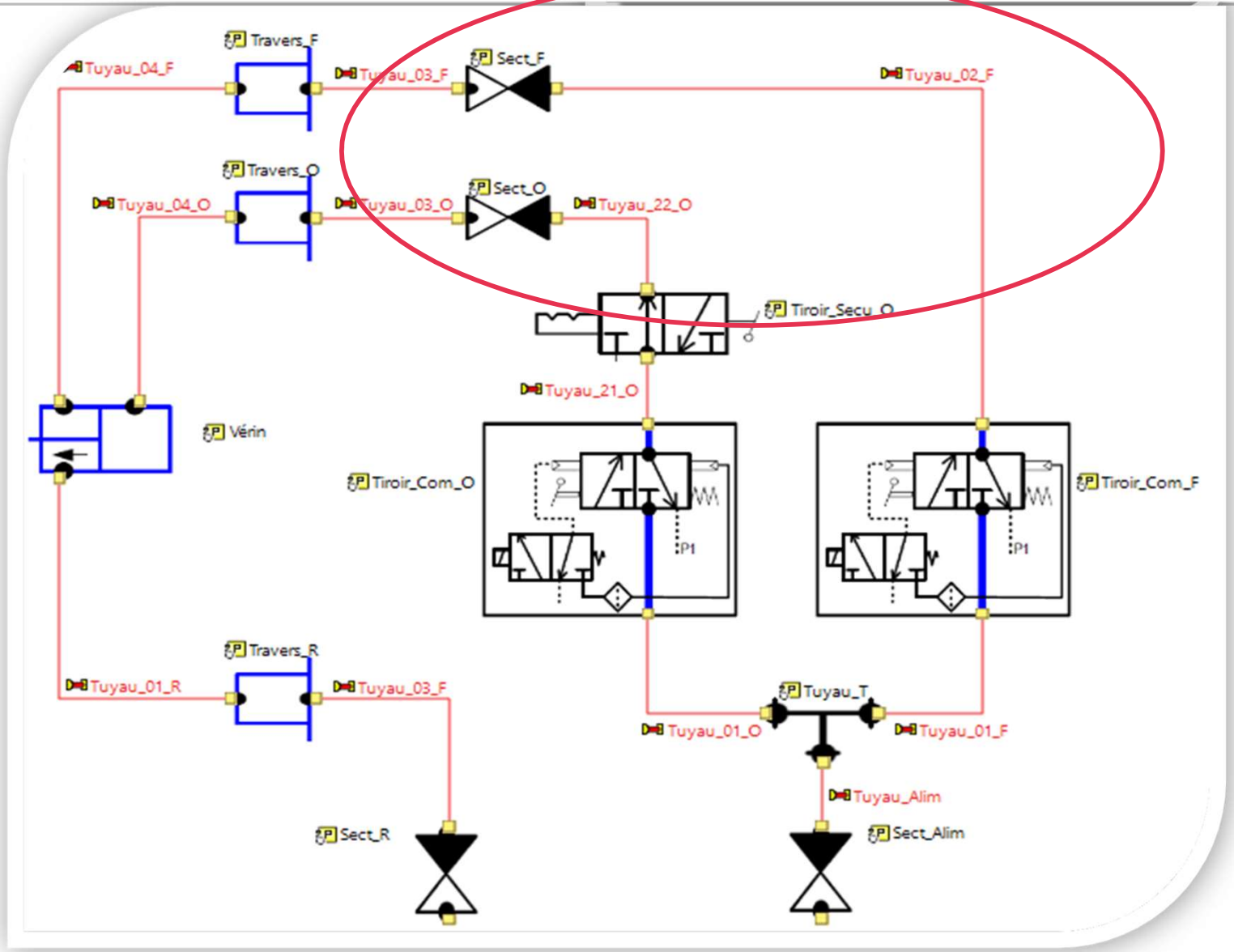
AN EXAMPLE FOR A HYDRAULIC SYSTEM (PID/PFD) – FOR DUMMY



=

To (emergency) STOP fluid flow

FUNCTION

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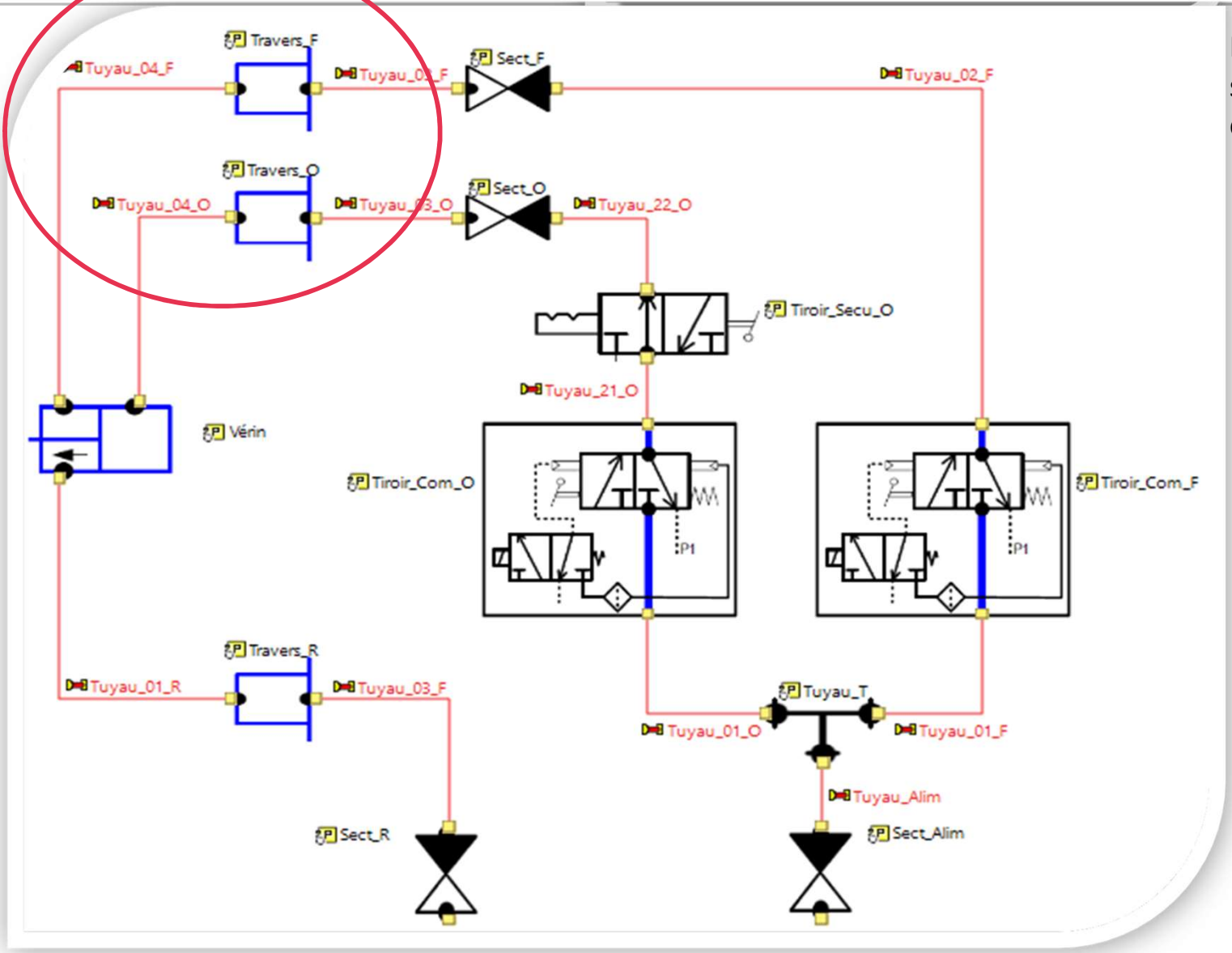
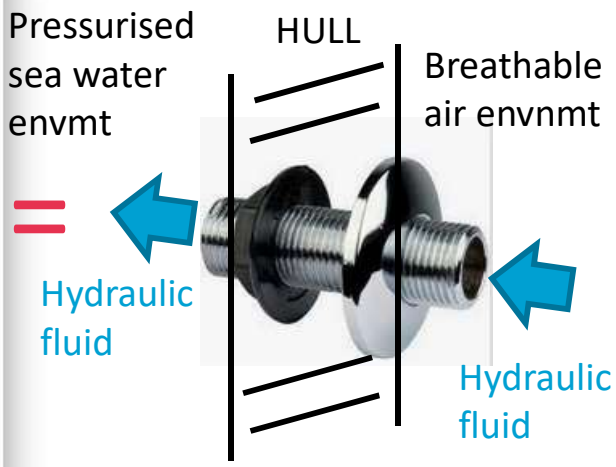
AN EXAMPLE FOR A HYDRAULIC SYSTEM (PID/PFD) – FOR DUMMY





Enable to CROSS two heterogeneous environments (ambiant air/pressurised sea water) surrounding the physical interface

FUNCTION

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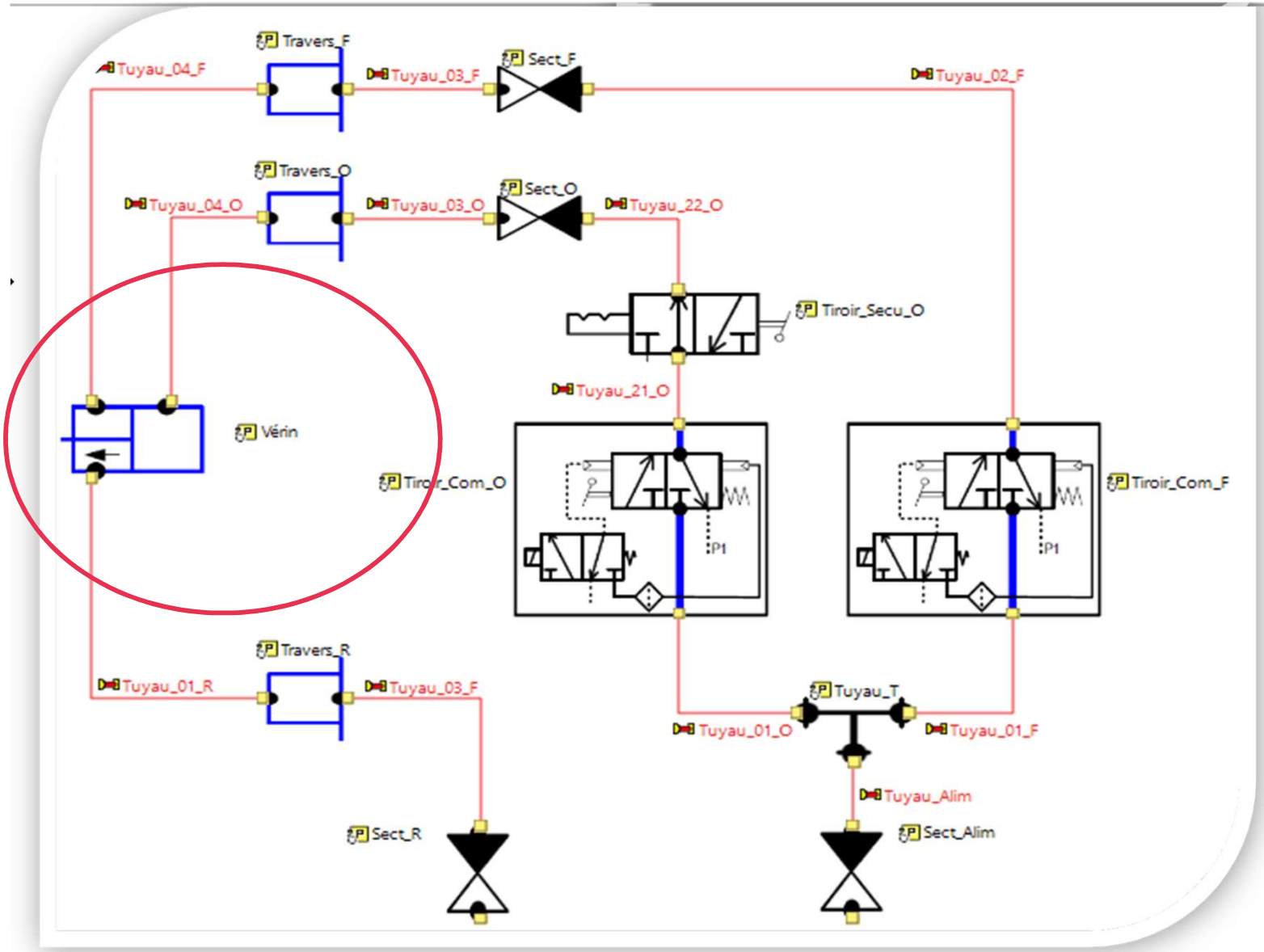
AN EXAMPLE FOR A HYDRAULIC SYSTEM (PID/PFD) – FOR DUMMY ☺



=

To push/pull (rudder blade)

[MAIN] FUNCTION

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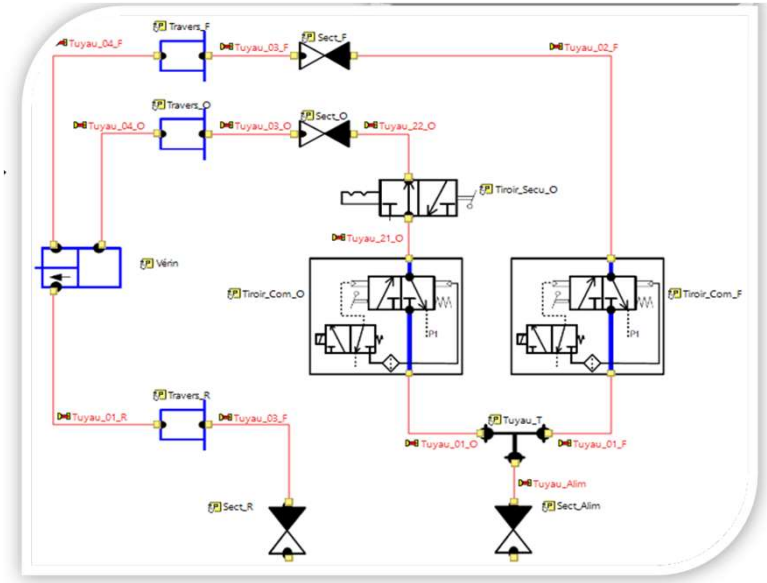
AN EXAMPLE FOR A HYDRAULIC SYSTEM (PID/PFD) – FOR DUMMY



Congratulations, you have achieved the « bronze » level on hydraulic system definition ☺

But as discovered, you must understand the symbols and what they mean!

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WHAT WE BUILT

- A catalog(-able) of (visual) symbols libraries mapped to « project-defined » equipements for all (engineering specialists) various domains, modifiable for each project w/o coding
- A way to assign a symbol/equipment to a « node » in the Capella's physical layer (using PVMT)
- An additional view to overlay an existing diagram, replacing the block symbol to domain-based symbol

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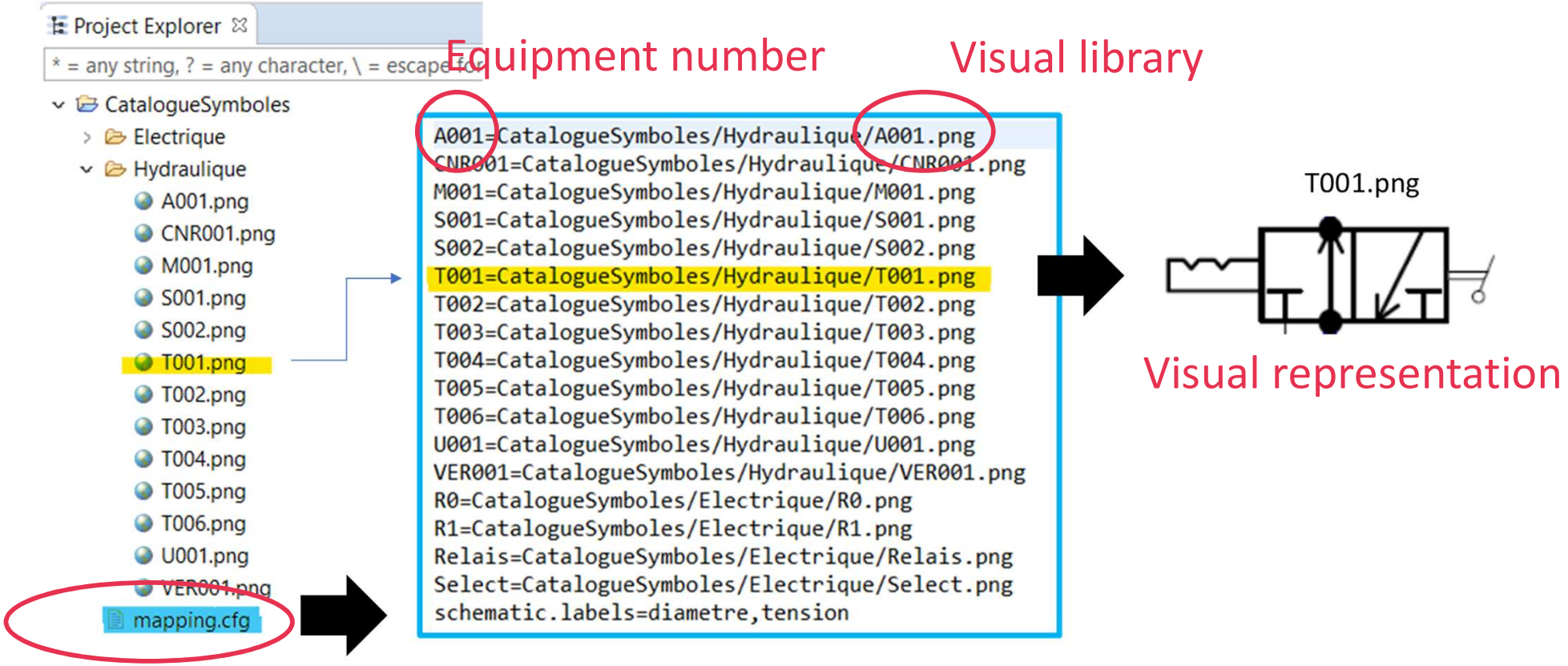
HOW IT WORKS
SCHEMATIC CATALOG



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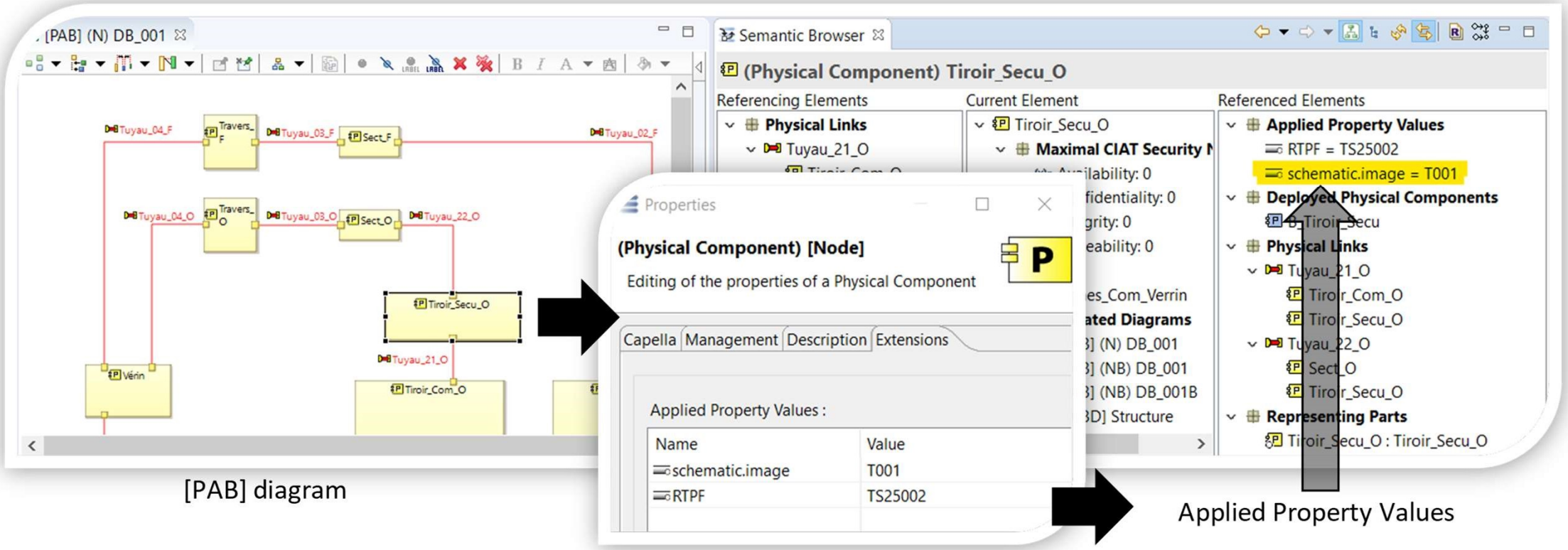
HOW IT WORKS
SYMBOL ASSIGNMENT

Symbol assignment to [Nodes]



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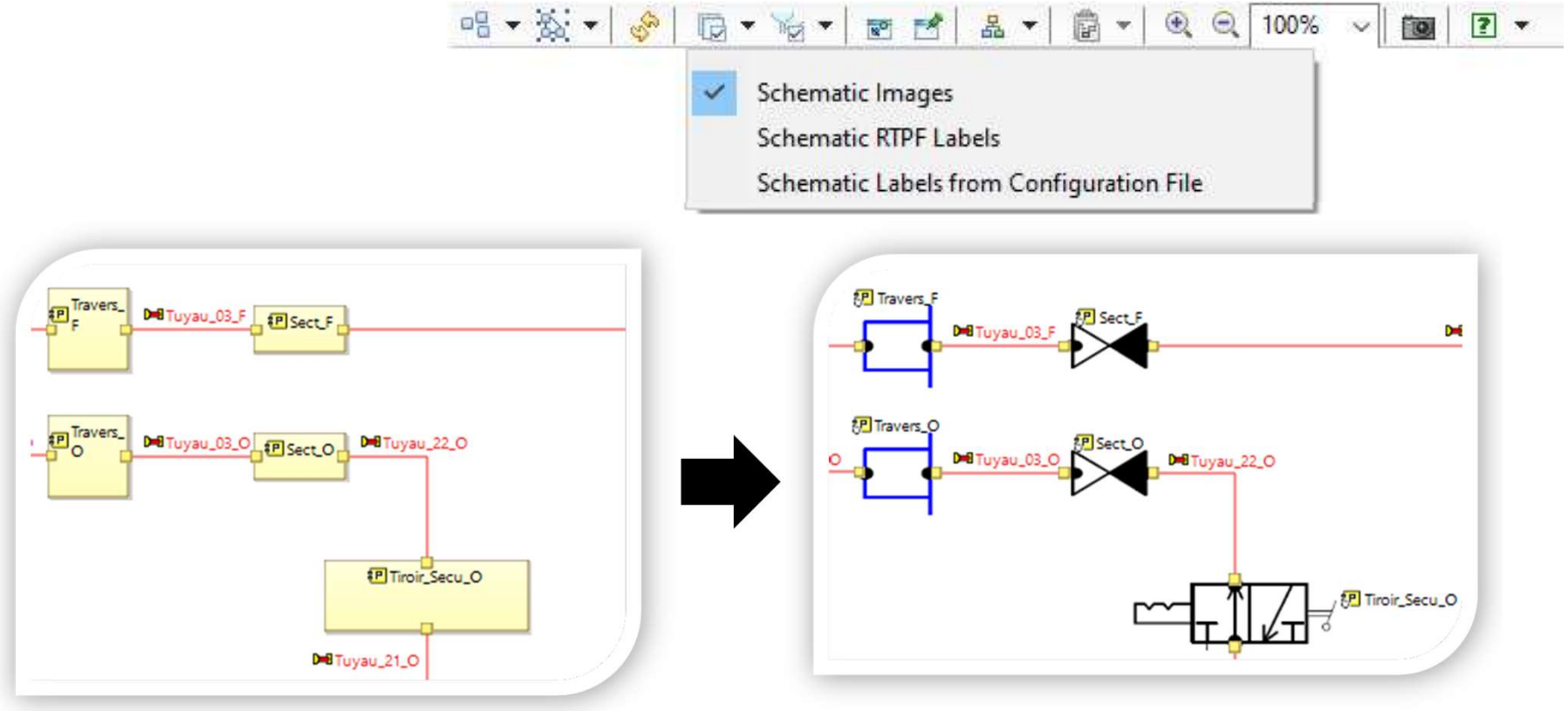
HOW IT WORKS
OVERLAY

Symbol display : **Layer** – *Schematic Images*



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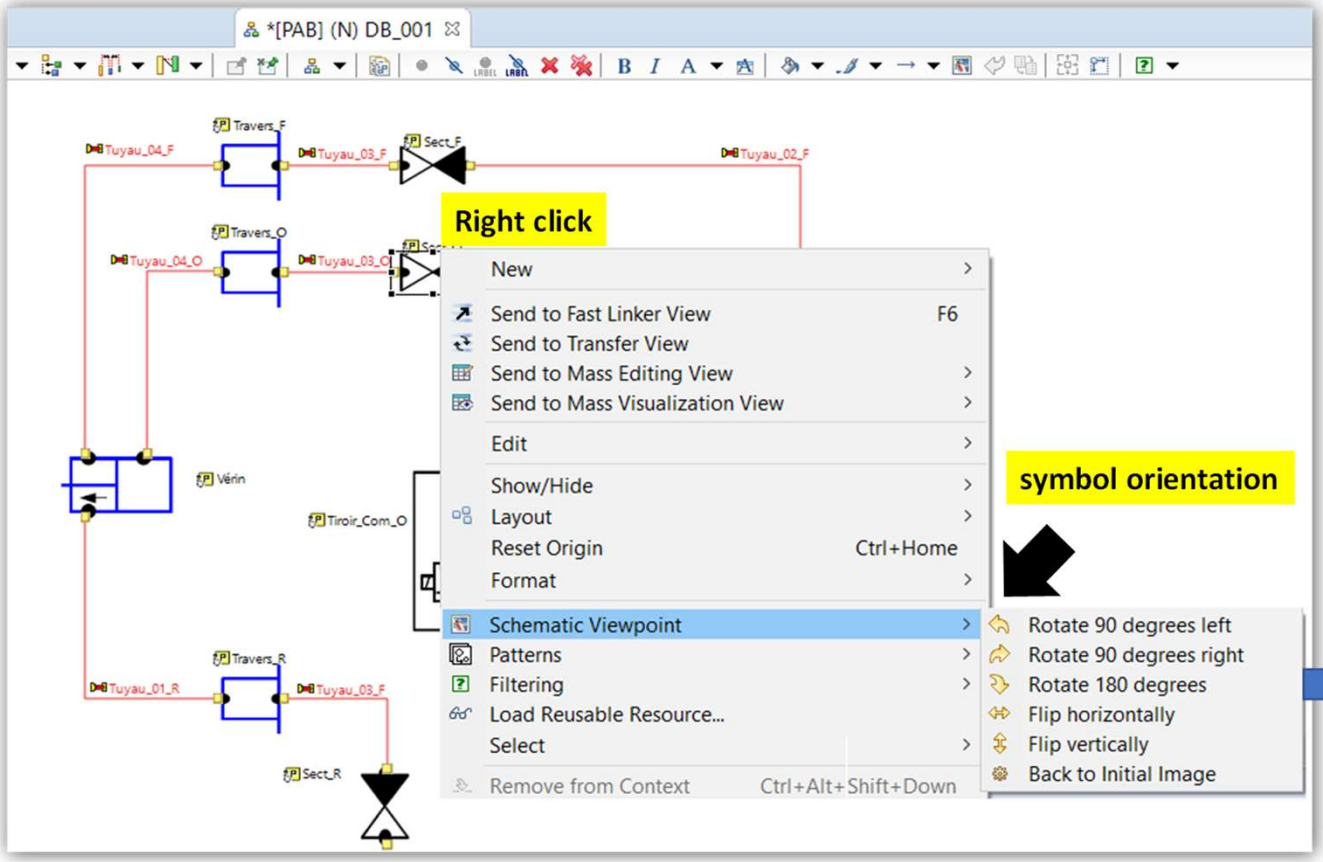
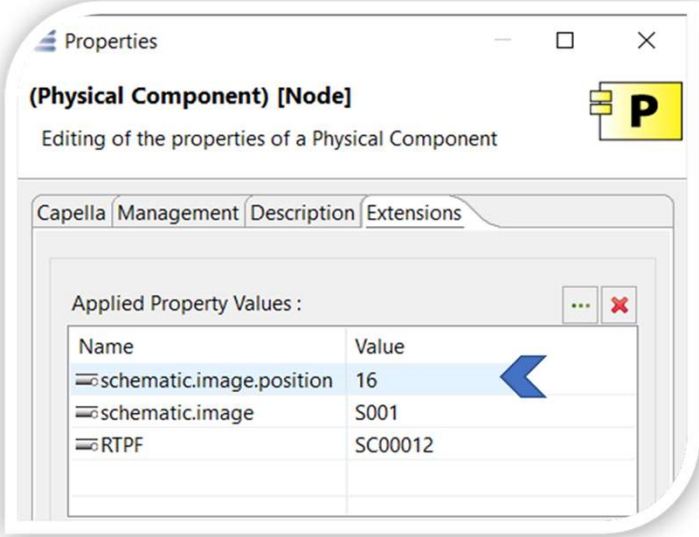
HOW IT WORKS
SYMBOL ORIENTATION

Symbol **orientation :** *(Right clic) contextual menu*





*Adds a new property that defines the symbols' **flip** and **orientation***

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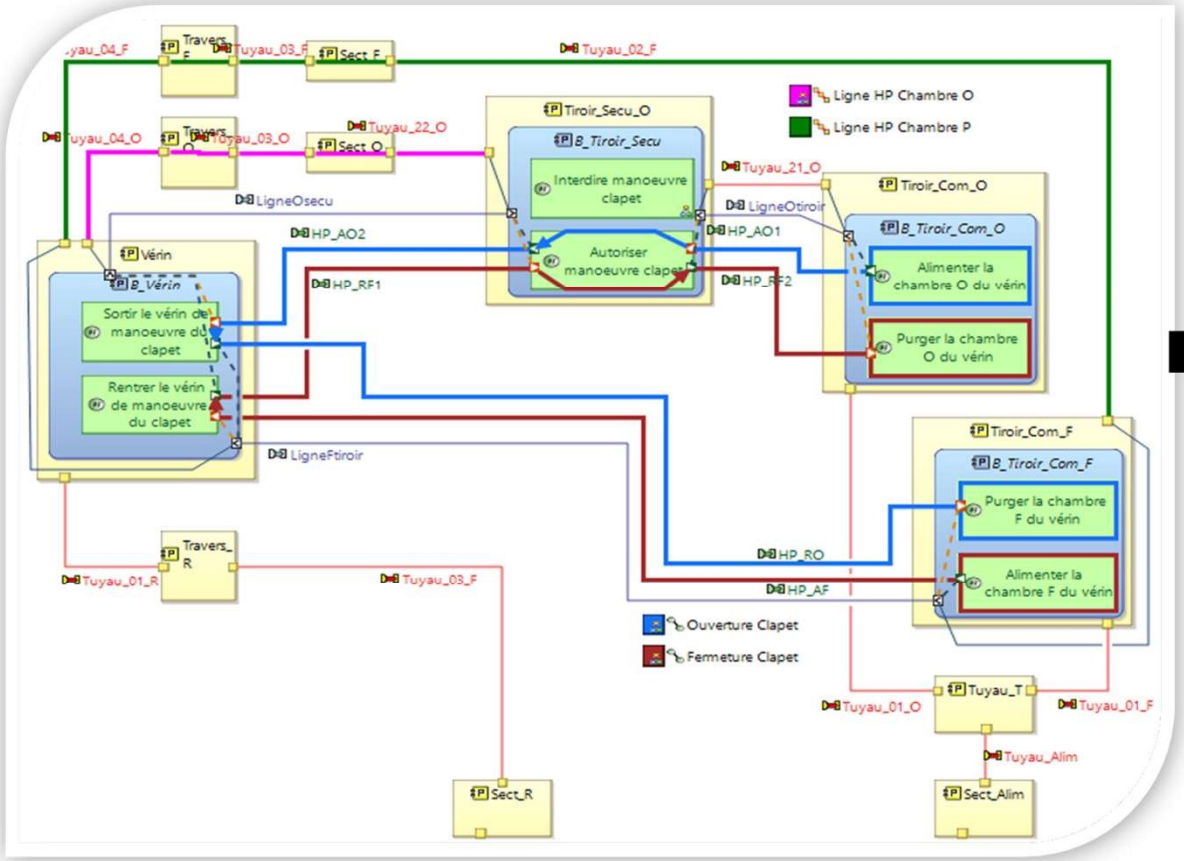
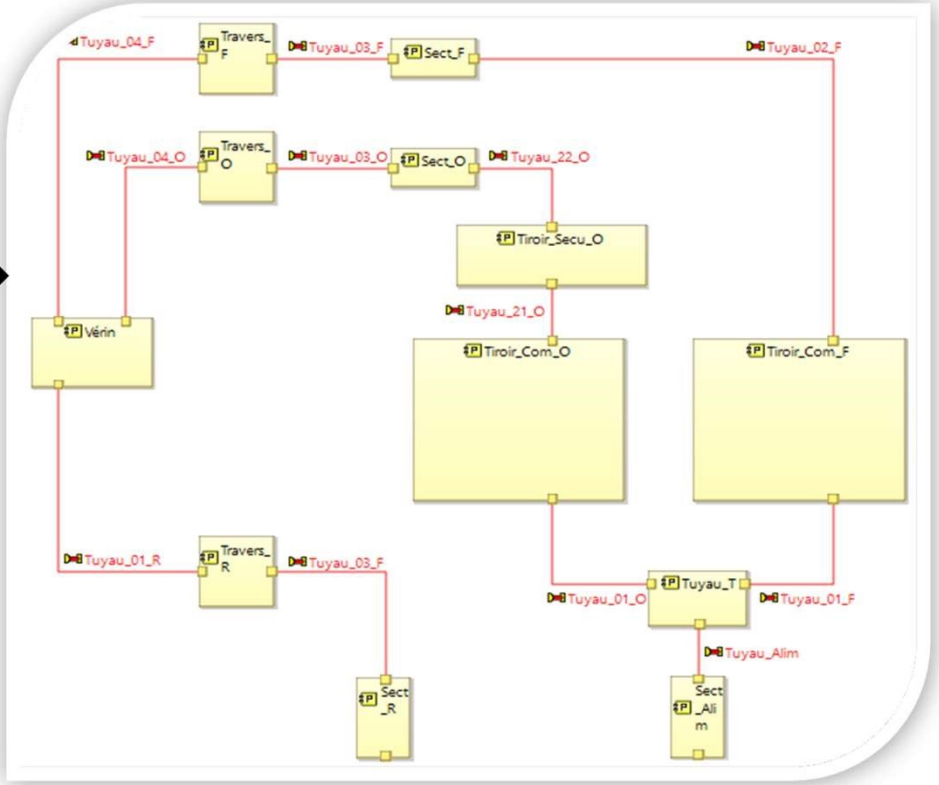
AN EXAMPLE (PHYSICAL LAYER)
AN HYDRAULIC SYSTEM ARCHITECTURE

[PAB] Overall view



[PAB] Nodes ONLY



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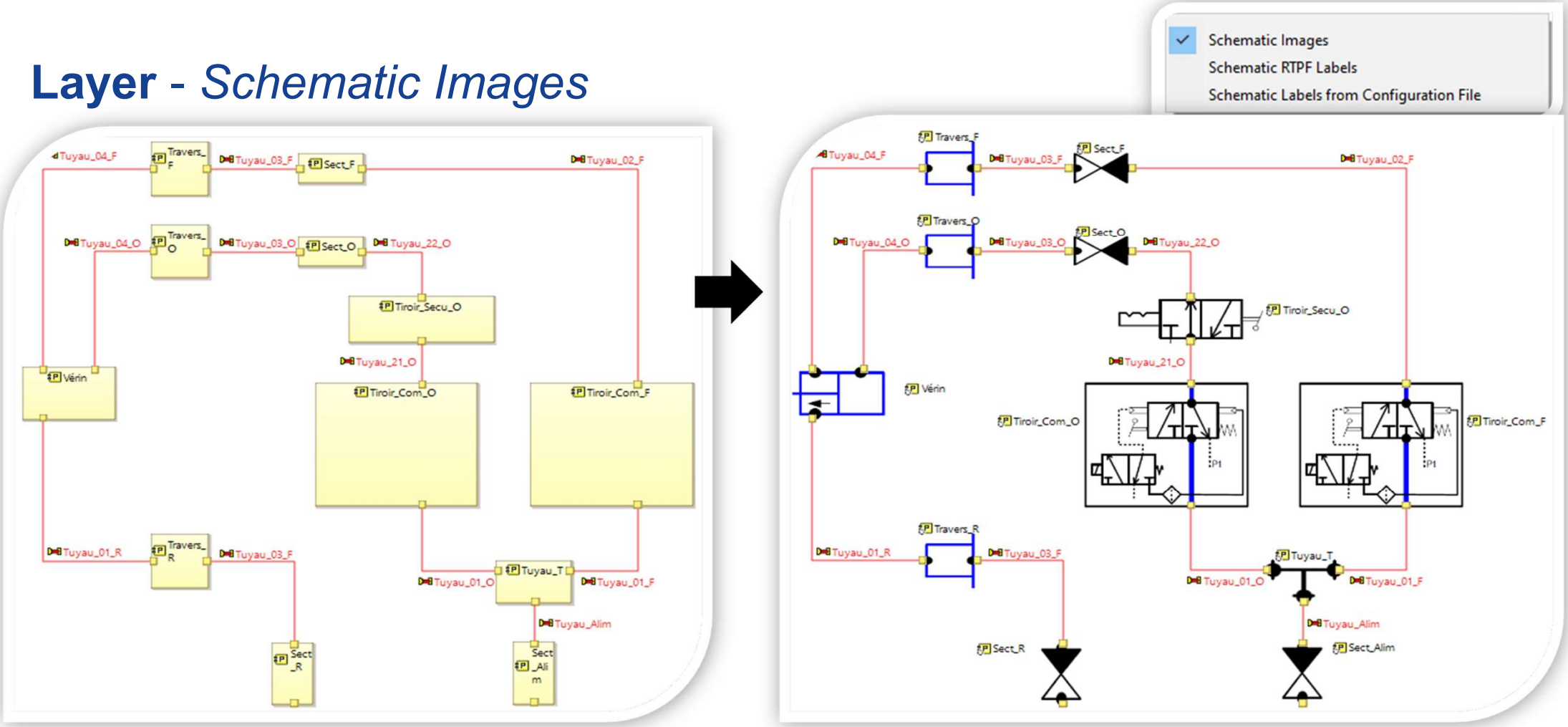
AN EXAMPLE (PHYSICAL LAYER)
FROM NODES ONLY (BLOCK SCHEMA) TO P&ID/PFD

Layer - *Schematic Images*



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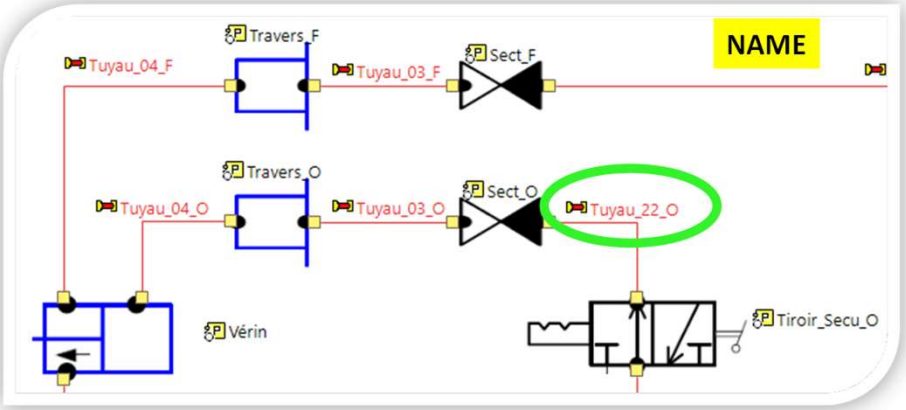
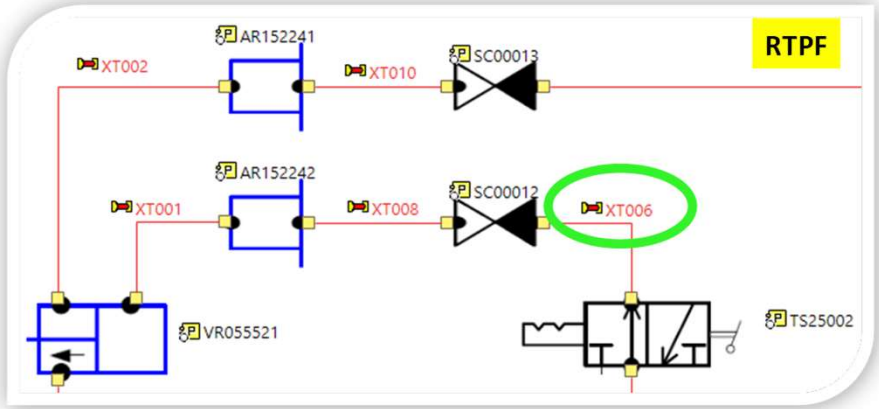
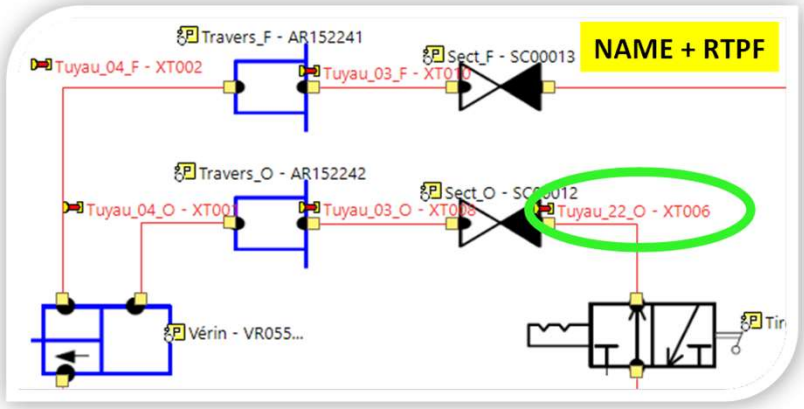
AN EXAMPLE (PHYSICAL LAYER)

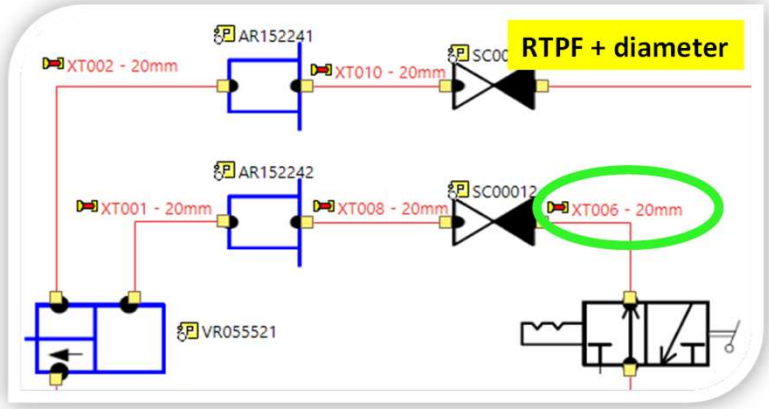
6 OPTIONS TO DISPLAY INFORMATION USING THE OVERLAY

3 schematic layers - 6 combinations









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SCHEMATIC ADDON LESSONS LEARNED

- Reconcile all engineering fields and knowledge into one repository (and model): the MBSE !

- Friendly-enough for « business user » however an enhancement would be required to be able to use PVMT « list » for selecting the right equipment based on conditions - *you're welcome to make it happening!*

Ideal for blueprint phase however for realisation phase (detailed design) the overall (Capella) project must be carefully designed (eg using libraries and potentially splitting it into smaller projects) as our data volume is fairly large at the equipments level (> 20.000). Both Capella and the addon have not been designed to handle such a volume in one model.

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BUSINESS USE CASES & CAPELLA'S ENHANCEMENT (ADDONS)

USE CASE #3
VISUAL TRACEABILITY ACROSS LEVELS: OA, SA, LA, PA

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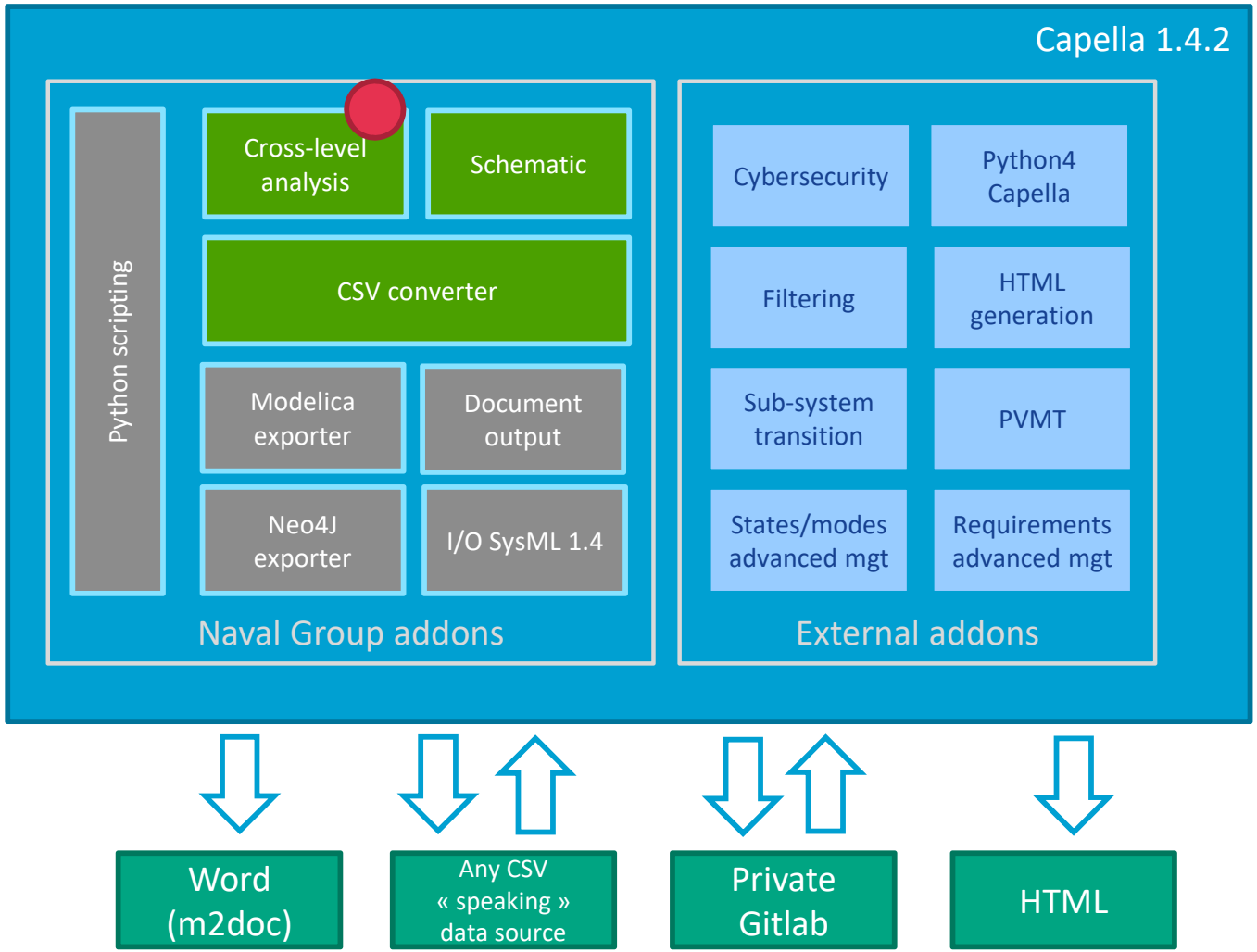
CROSS-LEVEL ANALYSIS



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CROSS-LEVEL ANALYSIS ADDON

One of the main objectives for using a MBSE is the ability to **justify** a design (solution) by being able to trace it back to the needs.

Capella does not offer out of the box a visual possibility to perform (output) it as a « diagram-like ».

You can navigate within the semantic browser from relationship to relationship however it is « user action-driven » and not an ouput-like diagram.

We decided to develop a generator that creates a new (static and final) diagram crossing all layers (top-down or bottom-up) showing realization « links » for a selected concept/element.

Why? To enable the traceability for a concept across all layers and visualising easily if the concept (equipment, function, etc) realises something « interesting » (eg best-value analysis) at the operational or system layer.

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CROSS-LEVEL ANALYSIS

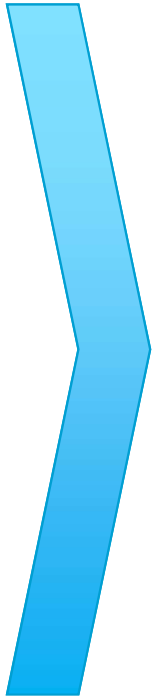
Cross analysis runs on any selected element, wherever it is:

Right-click selected element :

- On a diagram
- In the Explorer
- In the semantic browser

That belongs to any viewpoint

- Operational Analysis
- System Analysis
- Logical Architecture
- Physical Architecture



Cross Analysis > Init Cross Layers Diagram (CLD)

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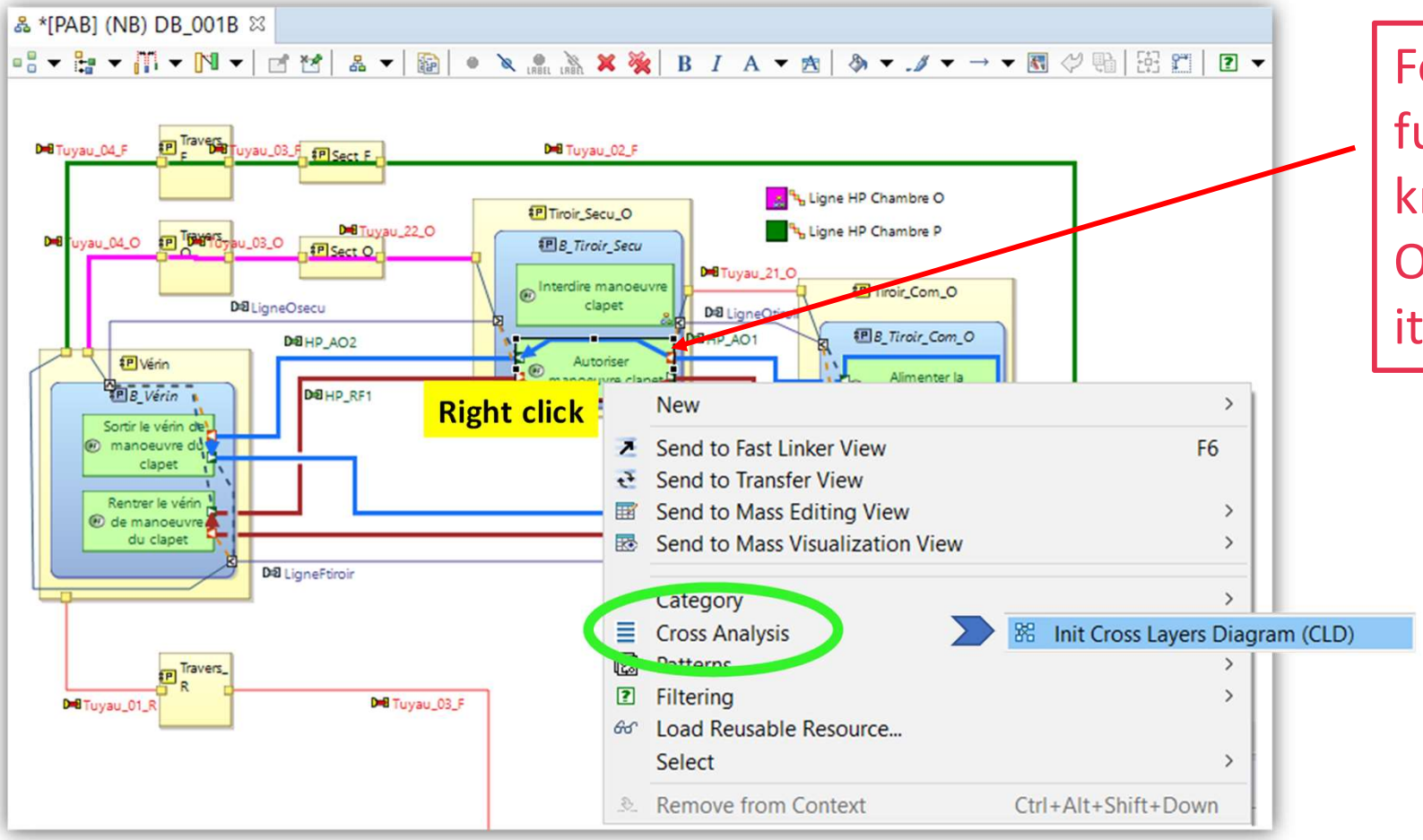
AN EXAMPLE (PHYSICAL LAYER)
AN HYDRAULIC SYSTEM ARCHITECTURE



For the selected function, we want to know to which Operational Capabity it is related

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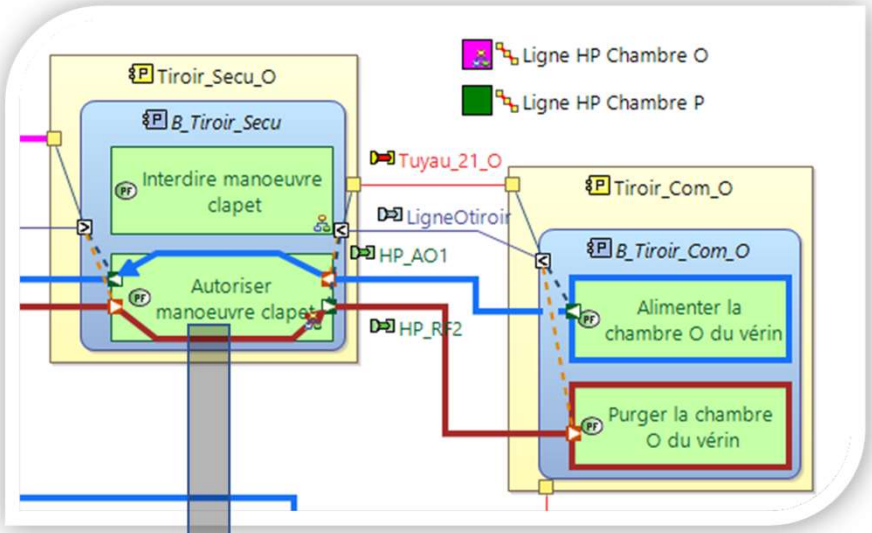
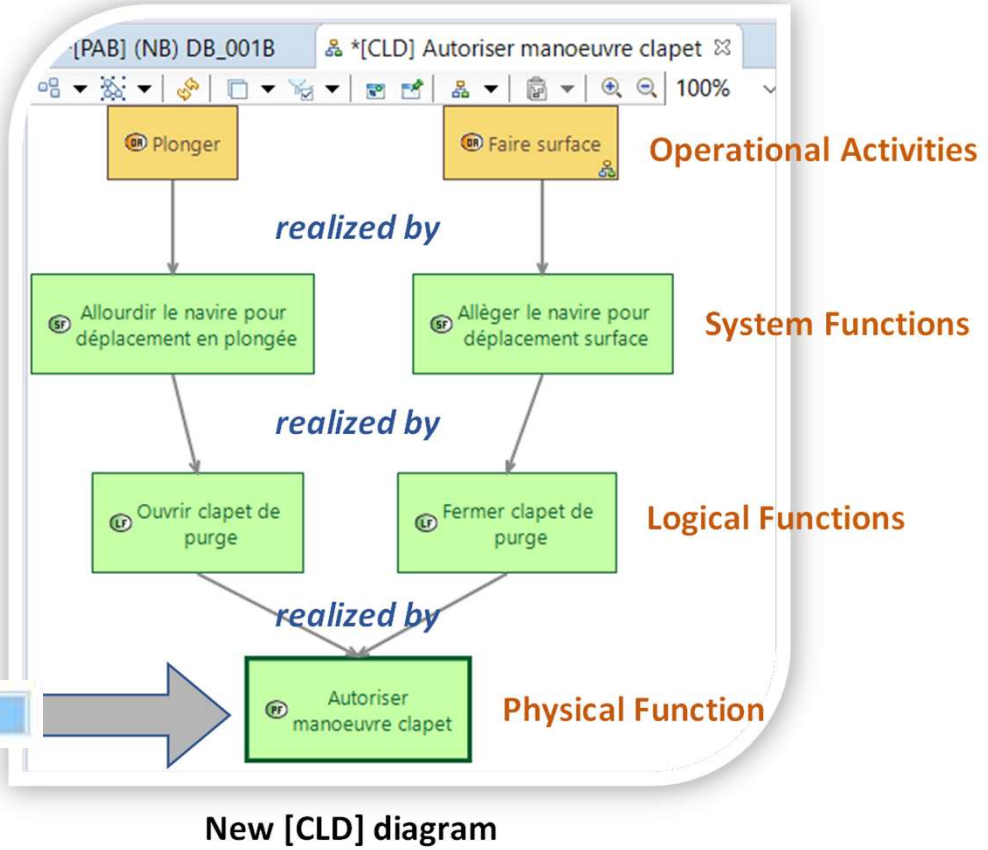
AN EXAMPLE
FROM PHYSICAL FUNCTION TO RELATED OPERATIONAL ACTIVITIES



Cross Analysis >

Init Cross Layers Diagram (CLD)



New [CLD] diagram

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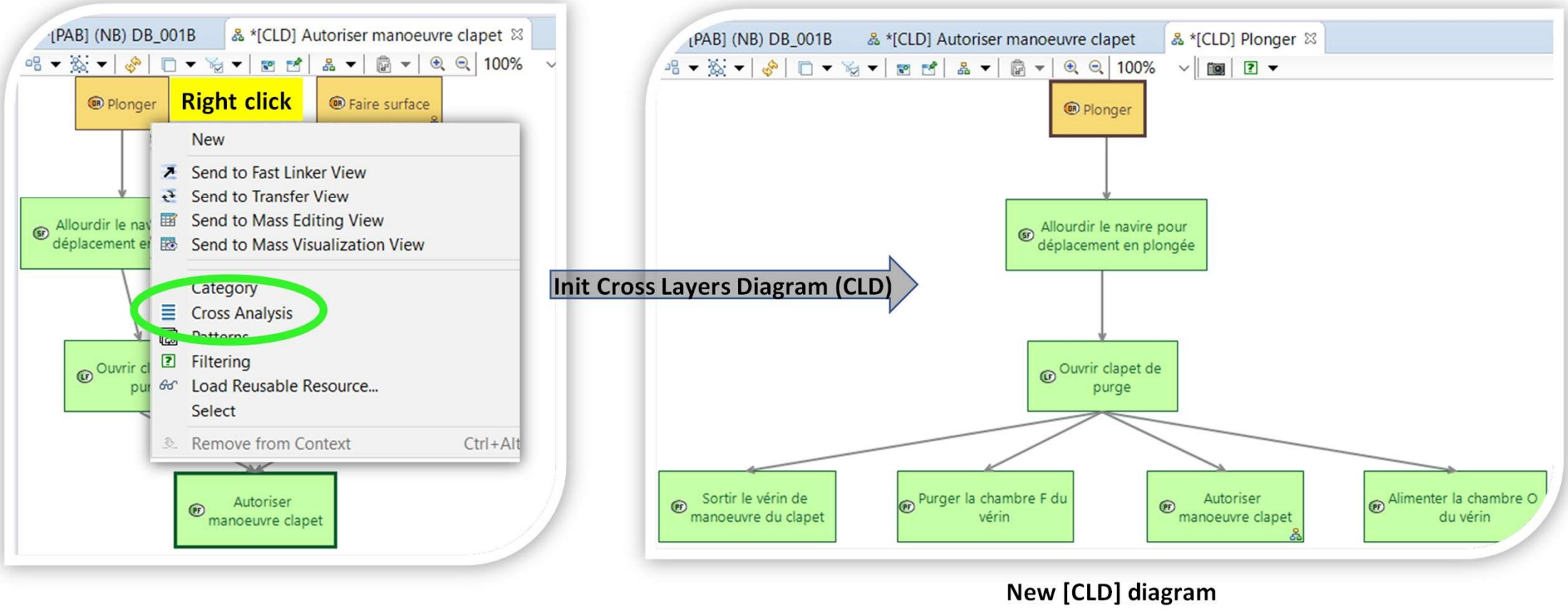
CROSS ANALYSIS

New step : right-click on related ***operational activity*** and use *Cross Analysis*



New [CLD] diagram

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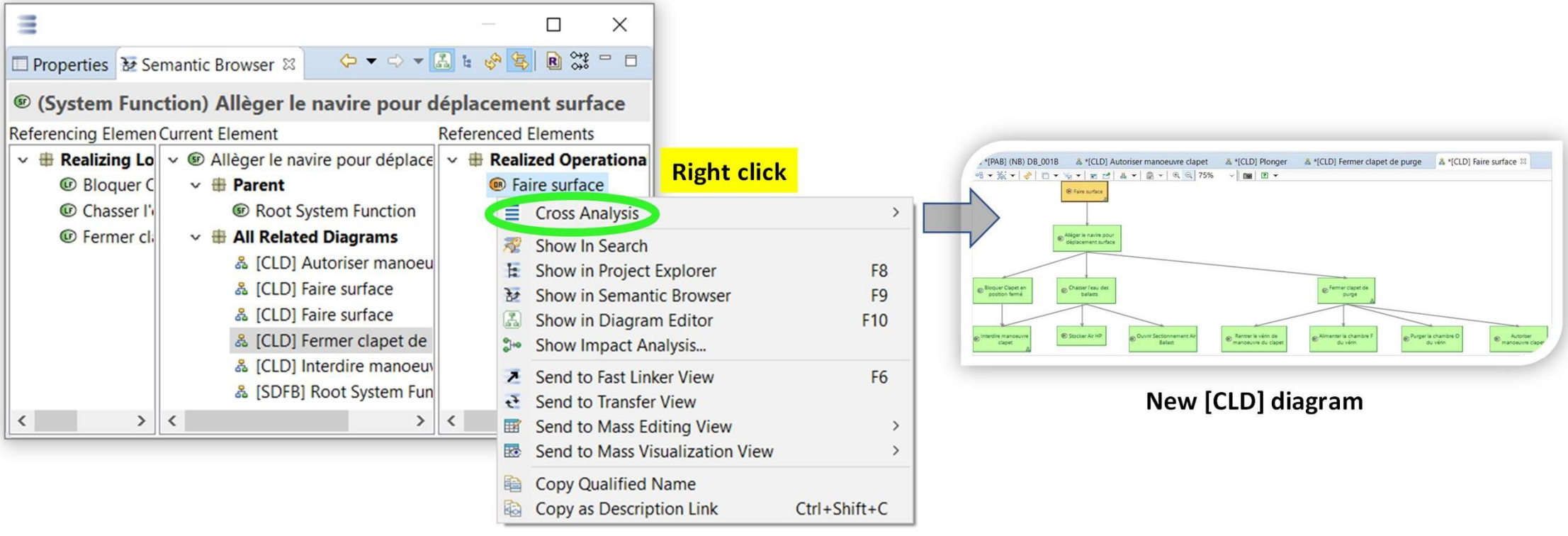
CROSS ANALYSIS

New step : right-click in the semantic browser



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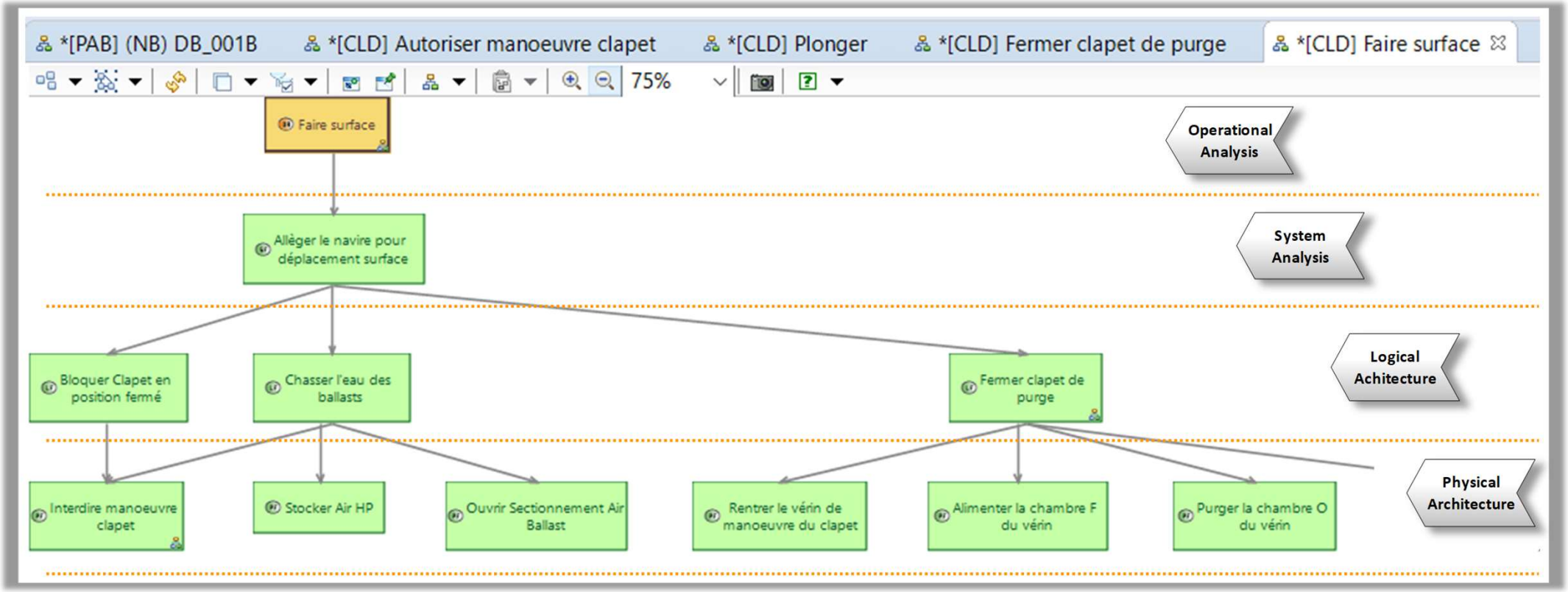
CROSS ANALYSIS

DEMO CROSS ANALYSIS

New [CLD] diagram



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THANKS FOR YOUR ATTENTION

YOU'RE WELCOME TO CONTRIBUTE TO MAINTAIN THE ADDONS ☺

WE ACCEPT VOLUNTEERS!

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