



2022 MELISSA CONFERENCE
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CREATING
A CIRCULAR
FUTURE

Specification process of a simulation platform for the MELISSA project



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Master Thesis

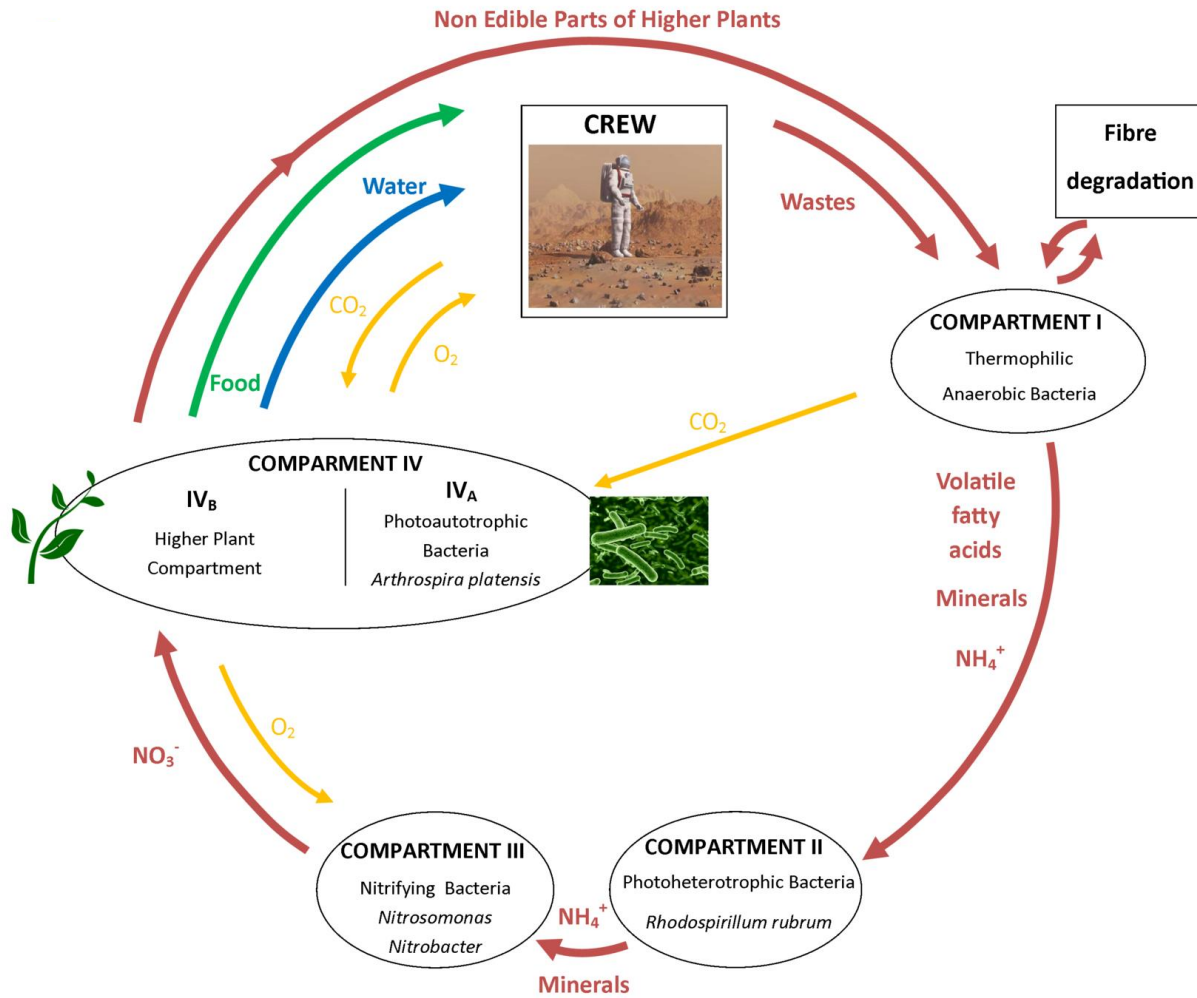
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Industrial Engineering Research Department (LGi)
In collaboration with ESA : C. LASSEUR & C. AUDAS



Specification process of a simulation platform for the MELISSA project

- 1. Context** : Why MELISSA needs a simulation platform ?
 - Existing work & Simulations needs
- 2. Audit** : What are the needs and challenges ?
 - Interviews & Audit synthesis
- 3. Literature review** : What can we learn from similar projects ?
 - LSS & Digital Tools for LSS
- 4. Gaps, proposals and perspectives** : How can we improve the simulation specification process ?
 - Simulation Request and Architecture
- 5. Synthesis & Conclusion**
 - Contributions & Next Steps

Context : Why does MELiSSA need a simulation platform ?



To better understand MELiSSA **performances**, especially in terms of **circularity**, we need a **global simulation platform**.

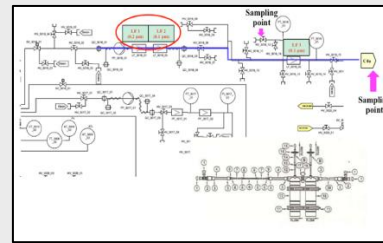
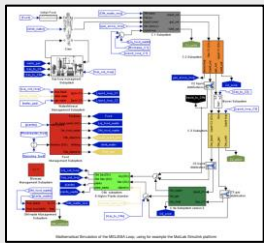
How can we **specify** this platform and extend it for **all terrestrial systems** in a **circular economy perspective**?

Extremely **complex closed loop** system, with many stakeholders

Context : Why does MELiSSA need a simulation platform ?

WHAT ALREADY EXISTS

Separate simulation models for each “Brick” with few interconnection between them and **different tools** (*Simulink, ProSim...*) Mainly **static**, no **control** laws



ALiSSE (*Advanced life support system evaluator*)



Collects data from the simulation models, adds **control laws** and provides **7 metrics**. Very **specific** to MELiSSA, **complex to use** and does not cover the **entire** loop



ESA’S NEED

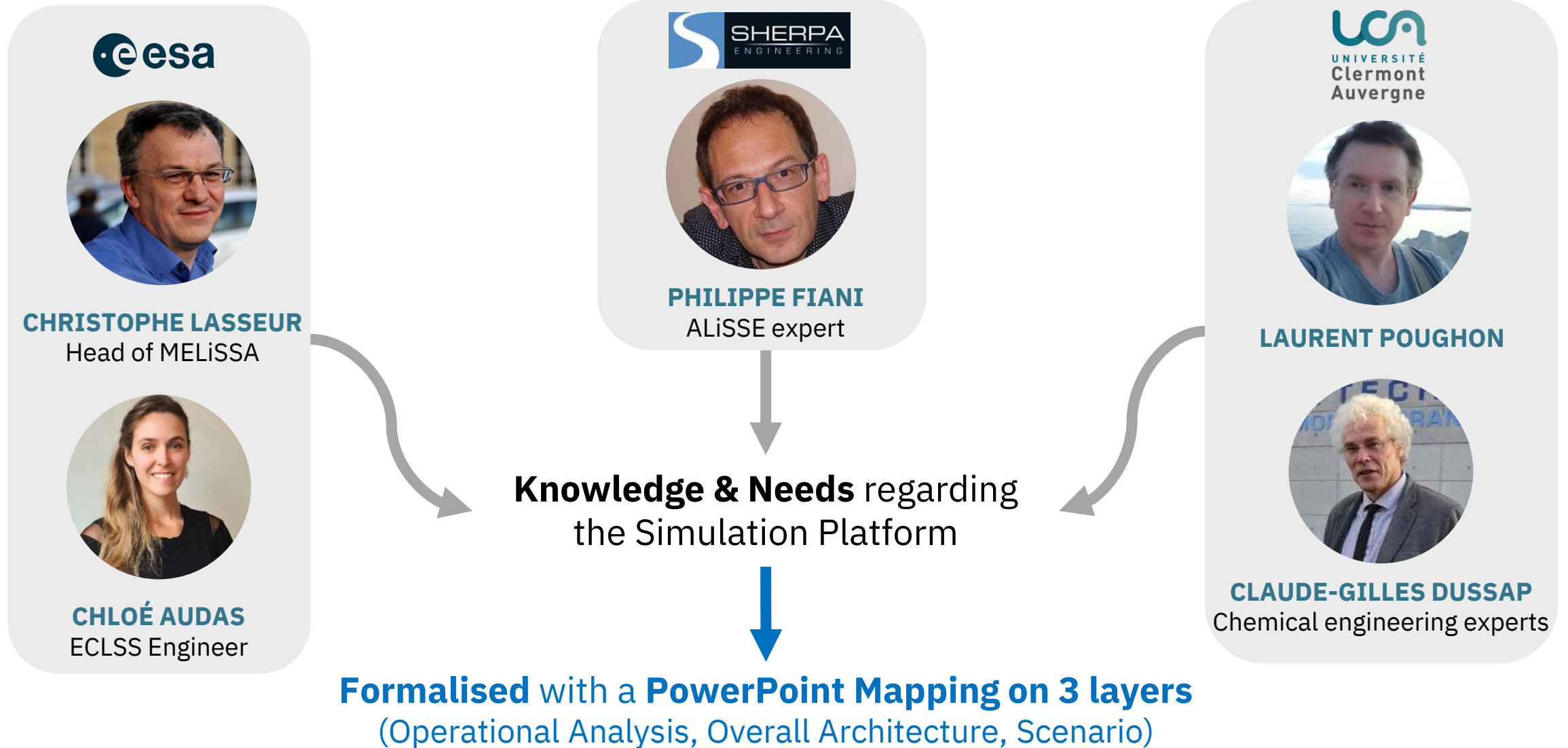
A dynamic simulator of the **entire MELiSSA Loop** :

- Compare diverse architectures /scenarios by computing their **circularity performance** (*Flows and Process*)
- Identify **limiting chemical components** (*What & When*) and the biological evolution
- **Flexible** : experts can add, remove and edit bricks
- **Unique** and interesting for **every stakeholders**
- Standard Platform able to adapt to **any circular economy systems**, including **terrestrial applications**



Audit : What are the needs and challenges ?

Interviews with 5 experts from different fields



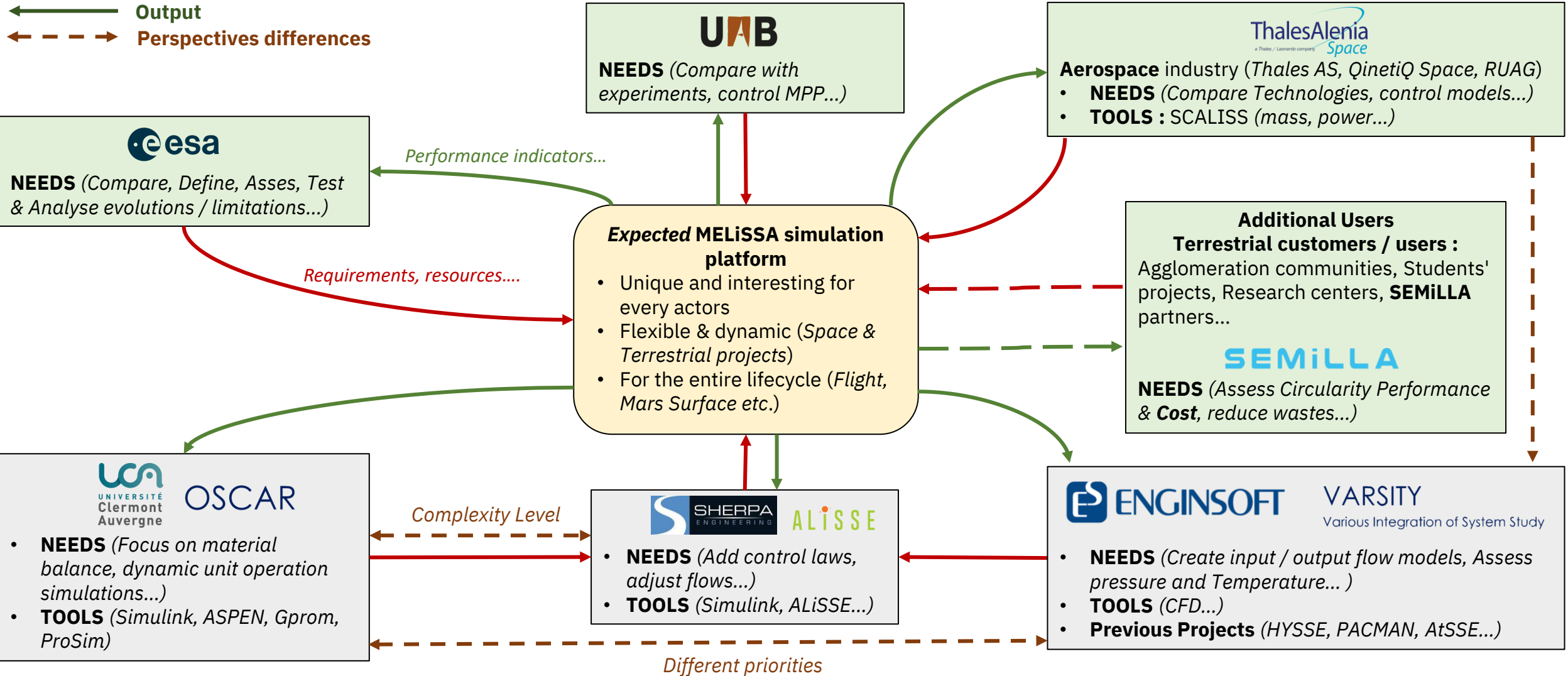
Stakeholders and Needs Mapping

Operational Analysis (Simplified)

CUSTOMERS / Users

PROVIDERS / Developers

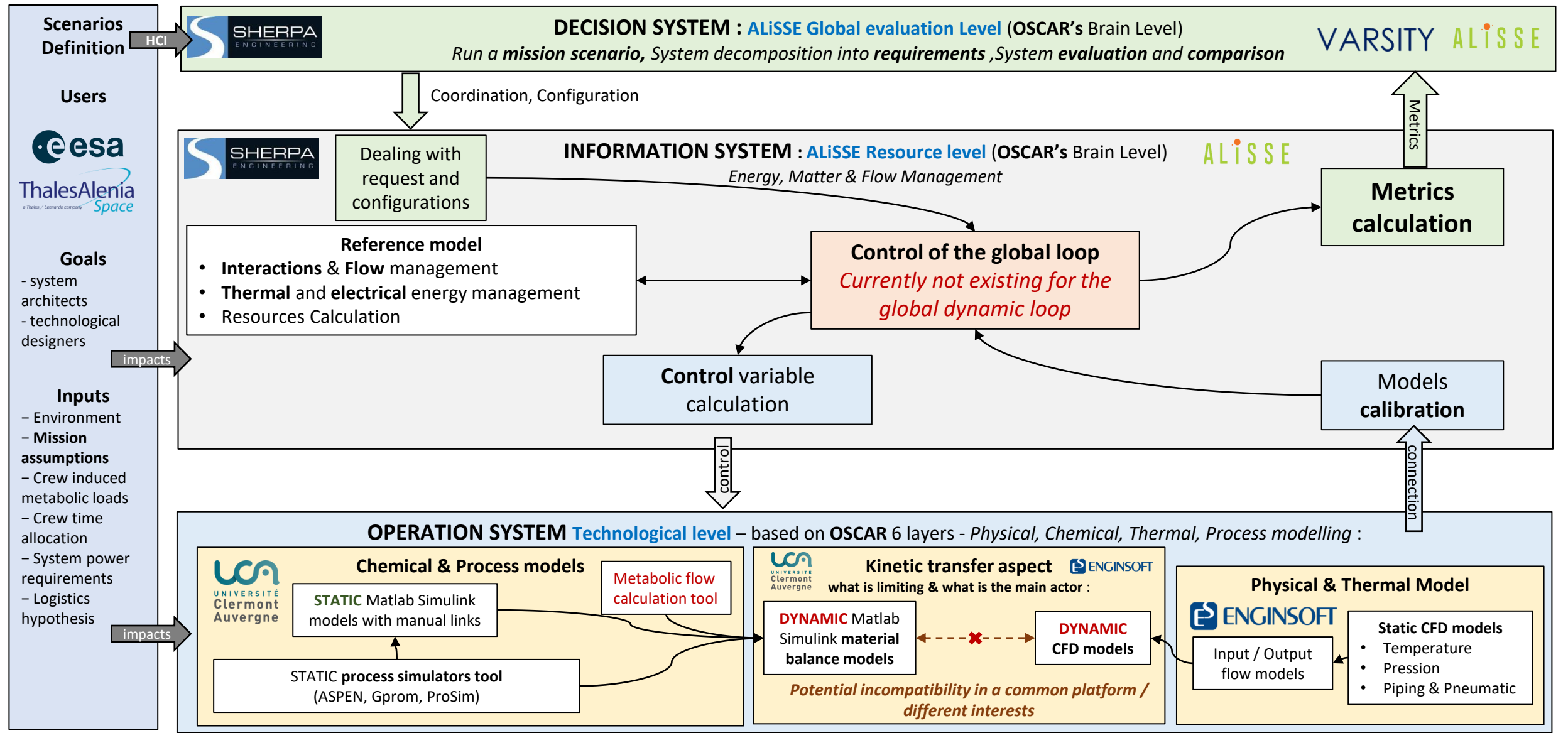
→ **Input**
← **Output**
- - - **Perspectives differences**



Detailed mapping available on request

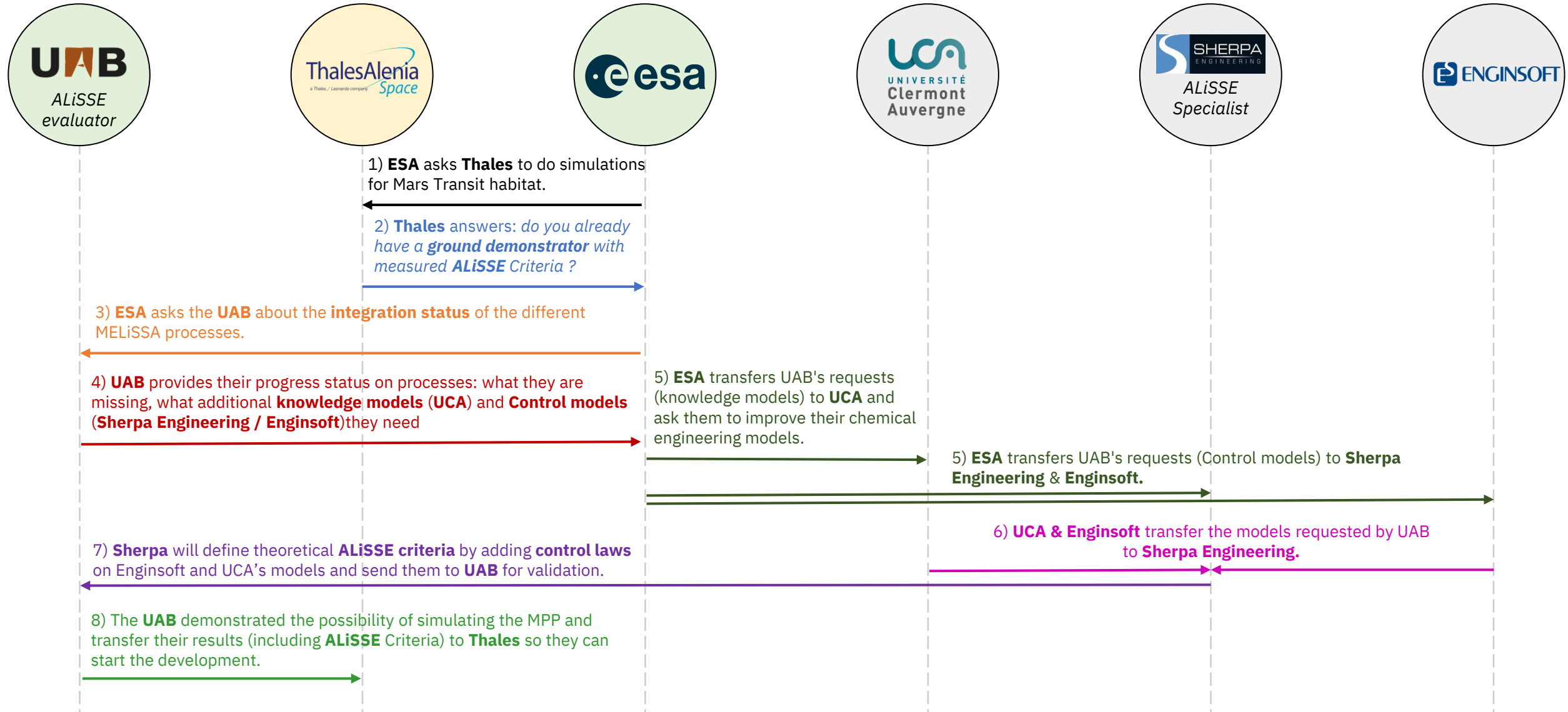
Stakeholders and Needs Mapping

Overall architecture of the simulation platform (Simplified)



Example : Simulation process

Sequence Diagram (8 steps)



Audit Synthesis : What are the needs and challenges ?

Several projects and tools already exist:

- Building on **previous** work
- **Integrate** existing tools at the right level in the future platform



Multiple diverse stakeholders:

- Different **interests** and **objectives** (*Trade-off between precision / flexibility / useability*)
- **Various** domains and expertise (*Chemical engineering / Systems Engineering/ Control / CFD / LSS*)
- Specific Methods and **Tools**

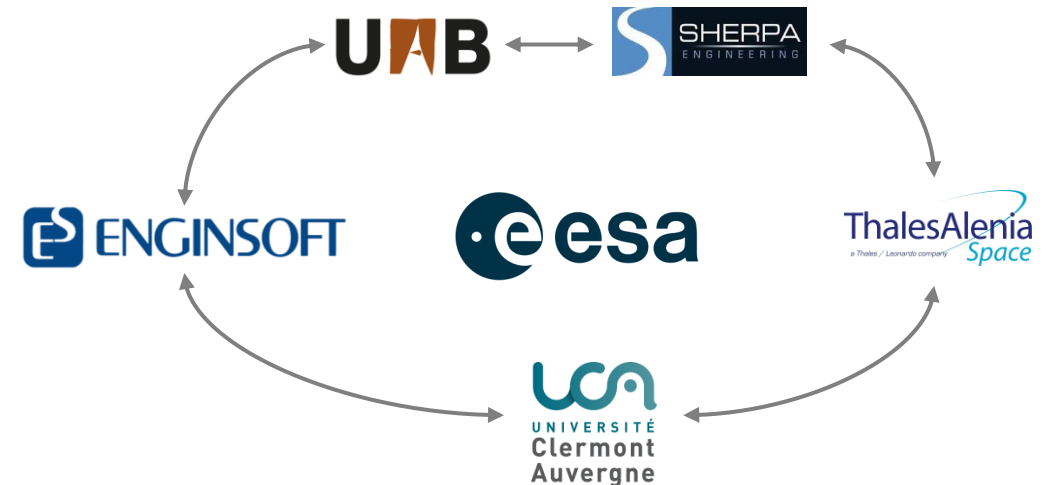


Technical Challenges:

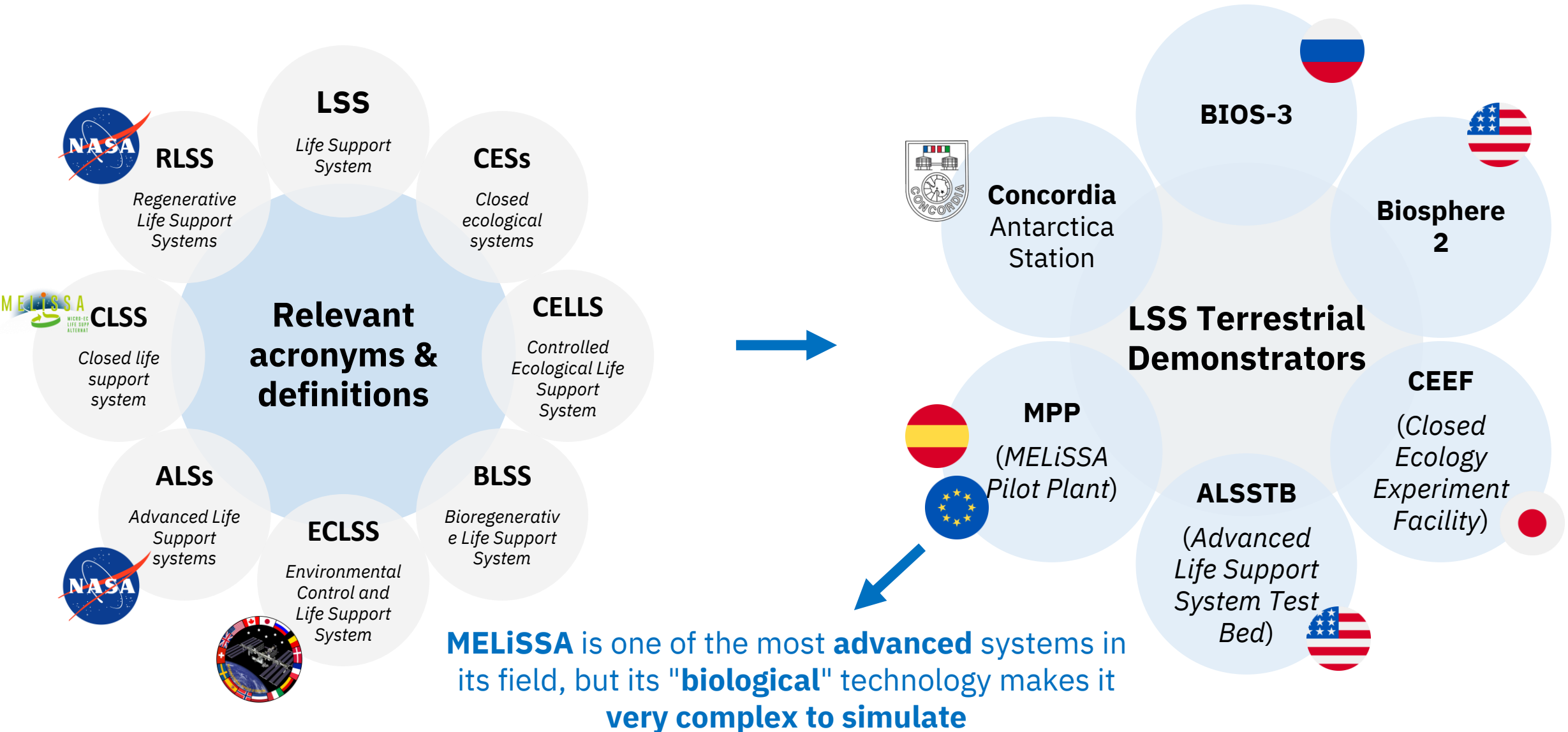
- **Interface** between the tools
- Dynamic closed loop : huge **stability** issues
- Adaptable to any **circular economy systems**, including terrestrial applications
- No similar commercial tool available

Human challenges:

- Involve every stakeholders
- Data Sharing



Literature review : What can we learn from similar projects ?



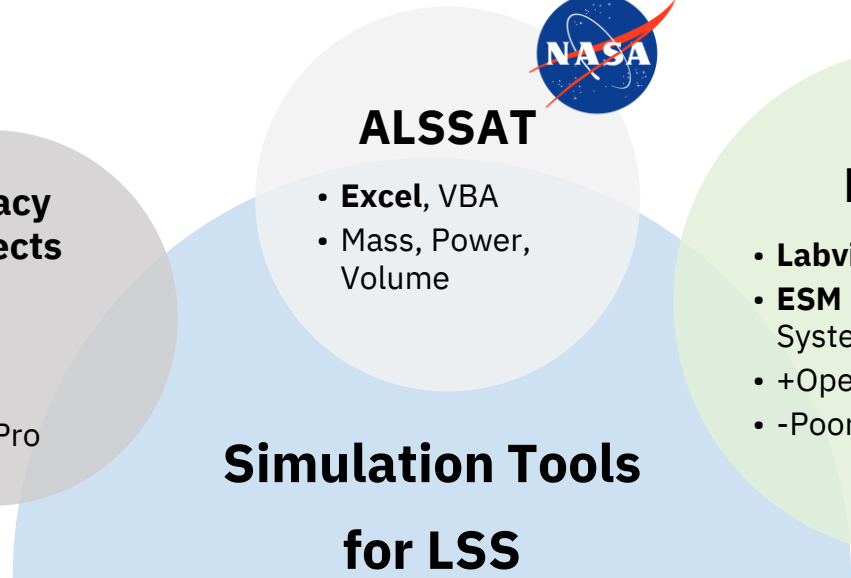
Definitions & References available on request

Literature review : What can we learn from similar projects ?

Most advanced tools
But not enough to meet ESA's need

Most advanced tools

But not enough to meet ESA's need



Legacy Projects

- G-189A
- CASE/A
- BioSim
- EcoSimPro

ALSSAT

- Excel, VBA
- Mass, Power, Volume

ELISSA

- Labview
- **ESM** : Equivalent System Mass
- +Open Source Library
- -Poor Algae Models

ALISSE

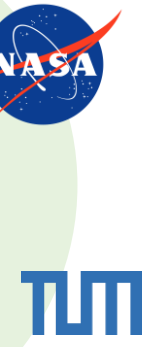
- Interface with **Simulink**
- +**Multicriteria**: Mass, Power, Crew Time, Risk, Reliability, Sustainability
- -Long simulation times, not user friendly

SCALISS

- **Java**
- Mass, Power consumption

V-HAB

- **Matlab**
- +**Multicriteria**: Stability, Controllability, Crew time
- +Modular structure
- -Poor Algae & Crew module compared to UCA



Detailed Inputs, Outputs, Limits & References available on request

Literature review : Synthesis & Gap

Many LSS simulation platforms projects have failed in the past

- **Long-term programs** \neq PhD projects
- **Technical complexity** of assembling numerous simulation models : diverse **methods and tools**.
- **Divergent expectations** and priorities between stakeholders.
- **Data sharing** : some actors may feel dispossessed of their work (*NASA Houston ELISSA example*).
- **Poor consideration of stakeholders' needs** during the specification phase: lack of interest at the end.

It is crucial to involve all stakeholders from the needs definition phase

- **Research gap** in the field of **simulations specification and architecture**
- The **improvement** of existing **methods** can prevent MELISSA from undergoing the same failures as similar projects
- **Similar gap** addressed by **IRT SystemX** (*J.-P. Brunet et al., 2020; Sohier et al., 2019, 2021*)



Gap : How to formalize simulation needs while ensuring traceability?

“Simulation Request” Process

Henri SOHIER



Mouadh YAGOUBI

1. Simulation **scope** & level of **detail** (*What part ?*)
2. **Objective**
3. **Quality, cost, and delivery** (*fast or accurate?*)
4. **Test scenarios** of the simulation
5. Data for simulation **calibration and validation**
6. Verification and validation (**V&V**) of the simulation

Results & Benefits

- ✓ Developed **software tools** to demonstrate their methods
- ✓ Linked **system architecture** (*MBSE*) with numerical simulations
- ✓ **Formalizes** the **exchanges** and requests between system and simulation architects
- ✓ Limits the **loss** of information and improve V&V
- ✓ Leverages **past** simulations

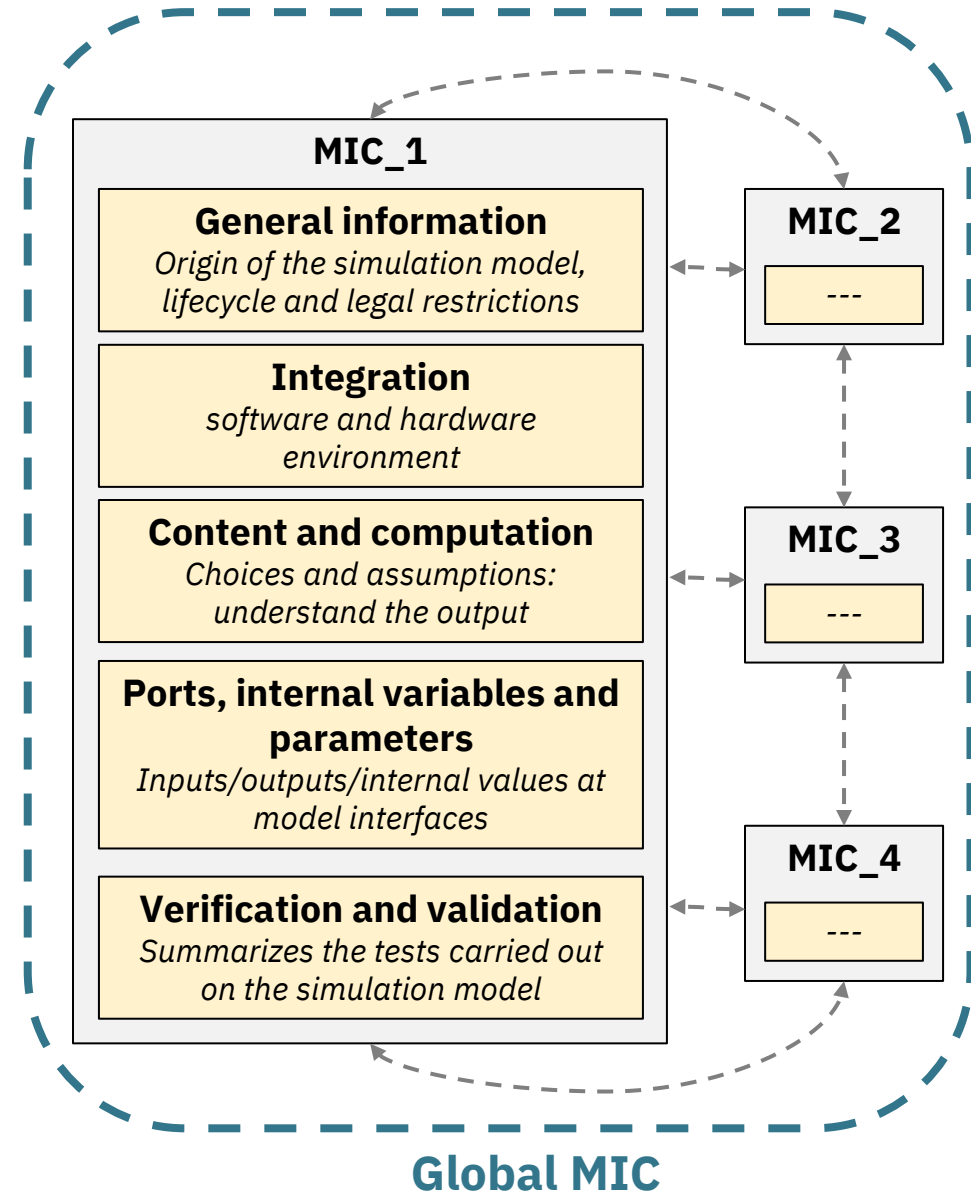
Gap : How to Support Simulation architecture ?

MIC : Model Identity Card (Goknur et al., 2015)



An Open-Source collaborative standard

- Simplify simulation models **specification, sharing** and **reusing**
- Standardized **interfaces** definition
- Helps to assemble **multi-disciplinary, multi-actors & multi-domain** simulation models
- List **key information** for characterizing simulation models with an **XML format** (software tool)
- Improve **traceability** with system requirements



Gap : How can we improve the simulation specification process ?

2 Different processes

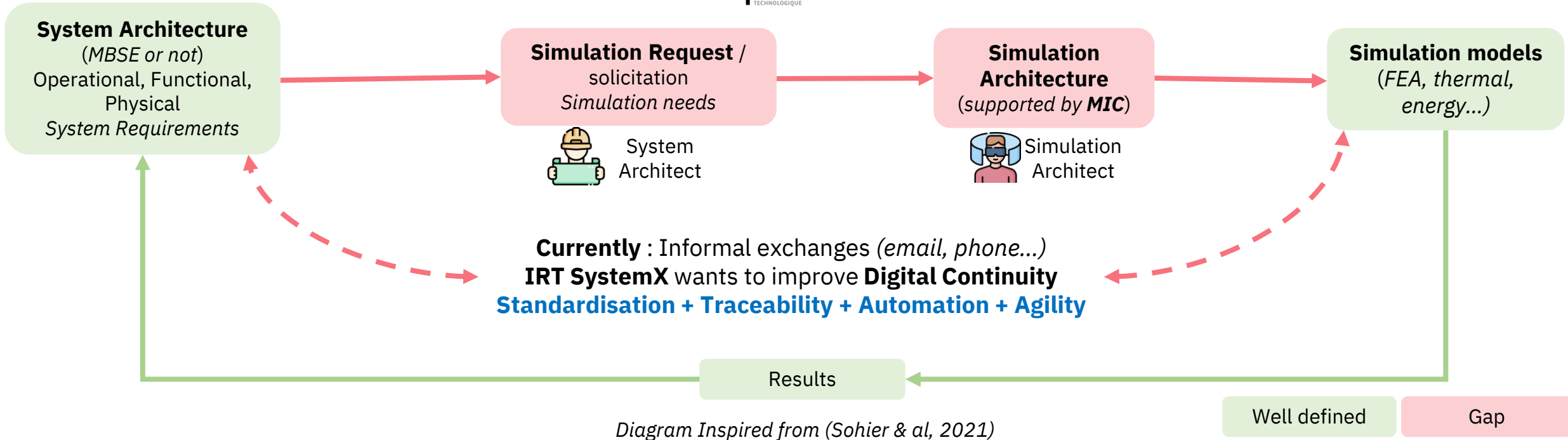


Diagram Inspired from (Sohier & al, 2021)

SET Level

Credible Simulation Process (Heinkel, 2021)

A method for the high-level project manager

Overview of an optimal sequential process for developing a simulation (*roles, resources*)

SET Level

Credible Simulation Process (2021)

- ✓ Useful for the **manager** to have an overview of an optimal sequential process
- ✓ Identify **Roles, expertise, inputs, outputs** required at each step

BUT

- ! Very **generic** / conceptual
- ! Requires **experience** to apply it



Simulation Request Process (2021)

- ✓ **Detailed** steps
- ✓ Strong **traceability** with system requirements, architecture and simulation needs
- ✓ **Software** Tooling

BUT

- ! Depends on custom **tools**
- ! Requires **highly detailed** System Architecture (**MBSE** preferred)

SET Level SystemX

MIC : Model Identity Card (2020)

- ✓ **Standardization** of simulation architecture
- ✓ Improves **connectivity** between models (*interface definition through XML*)

BUT

- ! Requires a strong simulation **expertise**
- ! Must be filled in by the simulation architect in a **dedicated tool**

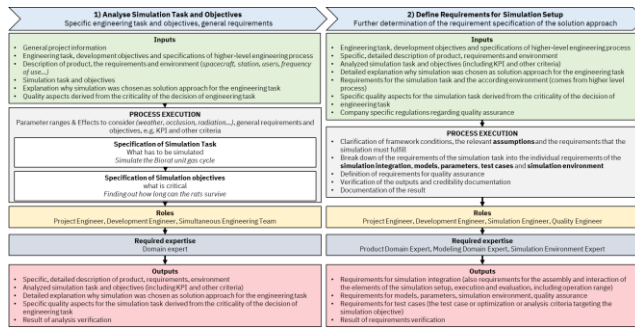
Difficult to apply fully in our academic context, but relevant for MELISSA

Proposal : Creation of Simplified PowerPoint Templates

Summarizes documents and interviews in a few slides (overview)

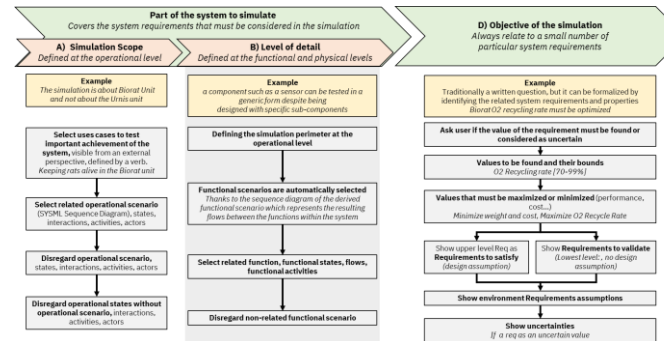
SET Level

Credible Simulation Process



SystemX
INSTITUT DE RECHERCHE TECHNOLOGIQUE

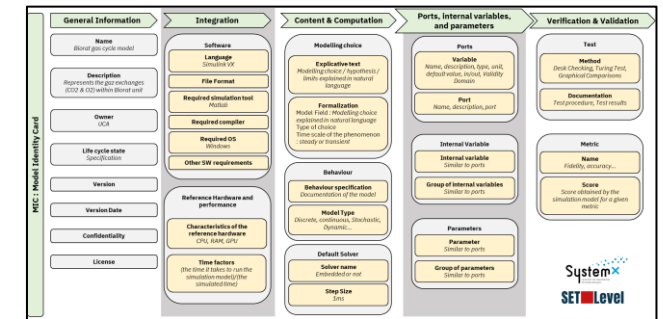
Simulation Request Process



SET Level

SystemX
INSTITUT DE RECHERCHE TECHNOLOGIQUE

MIC : Model Identity Card



Benefits

- ✓ Applicable to any complex systems: including **MELISSA** and **Circular Economy**
- ✓ Allow stakeholders to **compare** methods and **adapt** them to their needs
- ✓ **Optimize** collaboration, needs & simulation architecture definition : **“Top Down”** approach
- ✓ Move Towards : **standardization, connectivity, traceability, and digital continuity**

Perspectives

- ❗ **Customize** the templates for **Circular Economy features** (*budget*) and **indicators**
- ❗ Application of the methods by the **experts**
- ❗ BUT : the simulation platform remains **technically very complex** (*dynamic closed loop*)
- ❗ This methodological support is only part of the answer

Synthesis & Conclusion

Proposals to ESA and stakeholders

State of the art

- Existing **LSS/simulation tools**
- Criticalities & **challenges**

Mapping of the industrial audit

- **Interviews** synthesis
- 3 layers: support **communication** and **decision making**
- **Gap** identification

Comparison of 3 methods/tools to help specify the simulation platform and architecture

- **Advantages/Limits**
- **Templates** proposal
- **Perspectives**

Next Steps

Improve industrial audit

- Interview additional **stakeholders** (*MPP, THALES, EnginSoft, Circular Economy...*)
- Update the **Mapping**

Select with experts which methods could be applied

- Work with **SETLevel & IRT SystemX** to **adapt their methods** to the project (*Supported by the templates*)
- Implement **Circular Economy** aspects (*MFA, C-Indicators...*)
- Simulate **circularity performances** (*material and energy flows...*)

Dr. Cluzel's Presentation
at 8:50, session System
Studies 1/3



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& in the Master Thesis report*



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