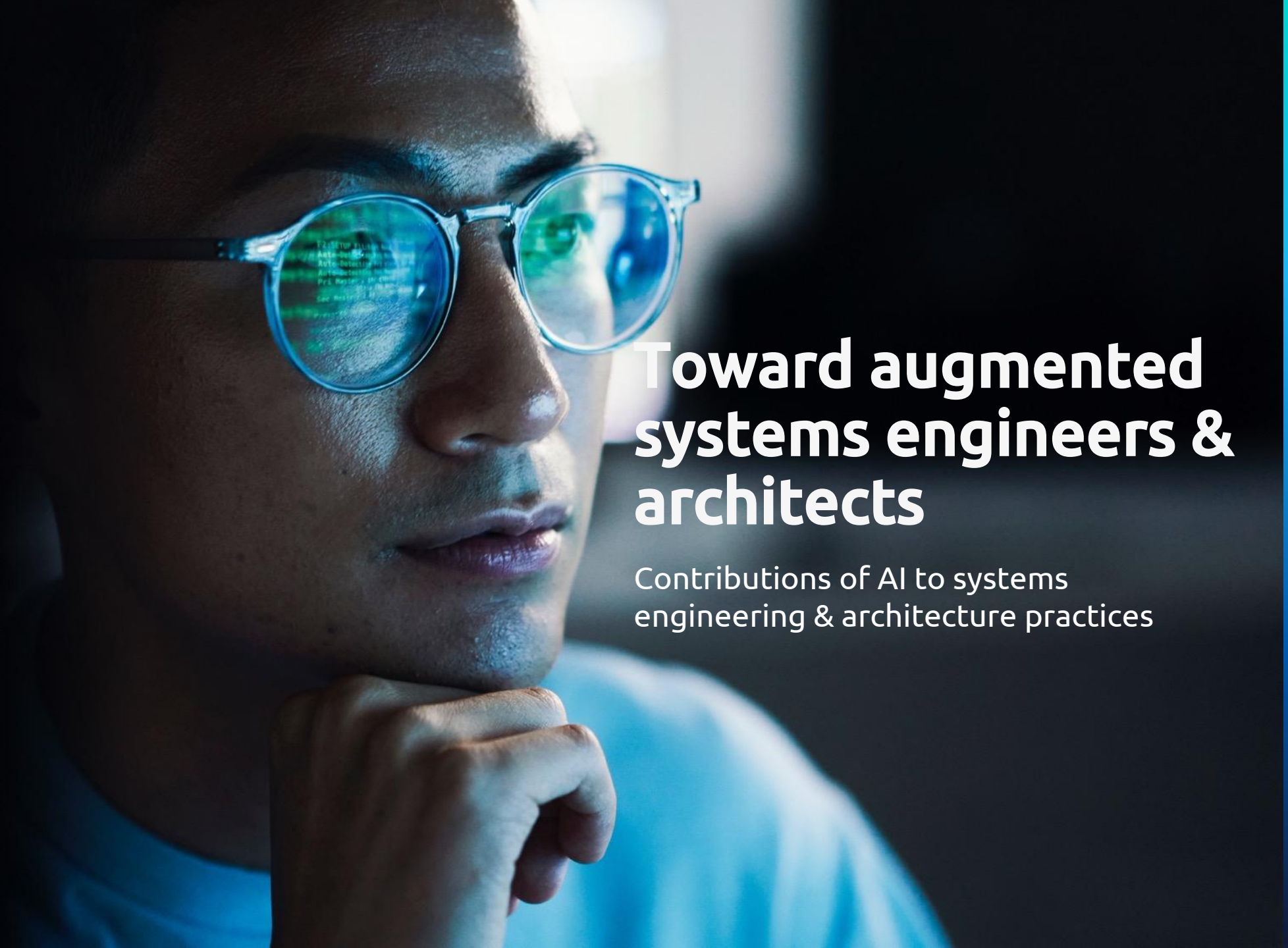


Toward augmented systems engineers & architects

Contributions of AI to systems engineering & architecture practices

Laure BUSSY

Yannis LAVIGNE

Hanish SAINI

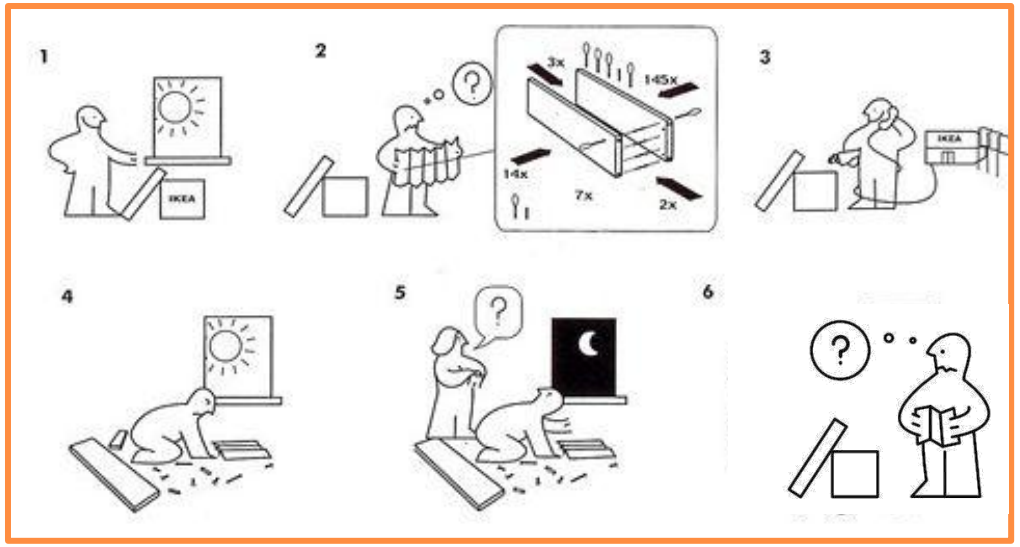
AFIS

Journée Thématique Itinérante

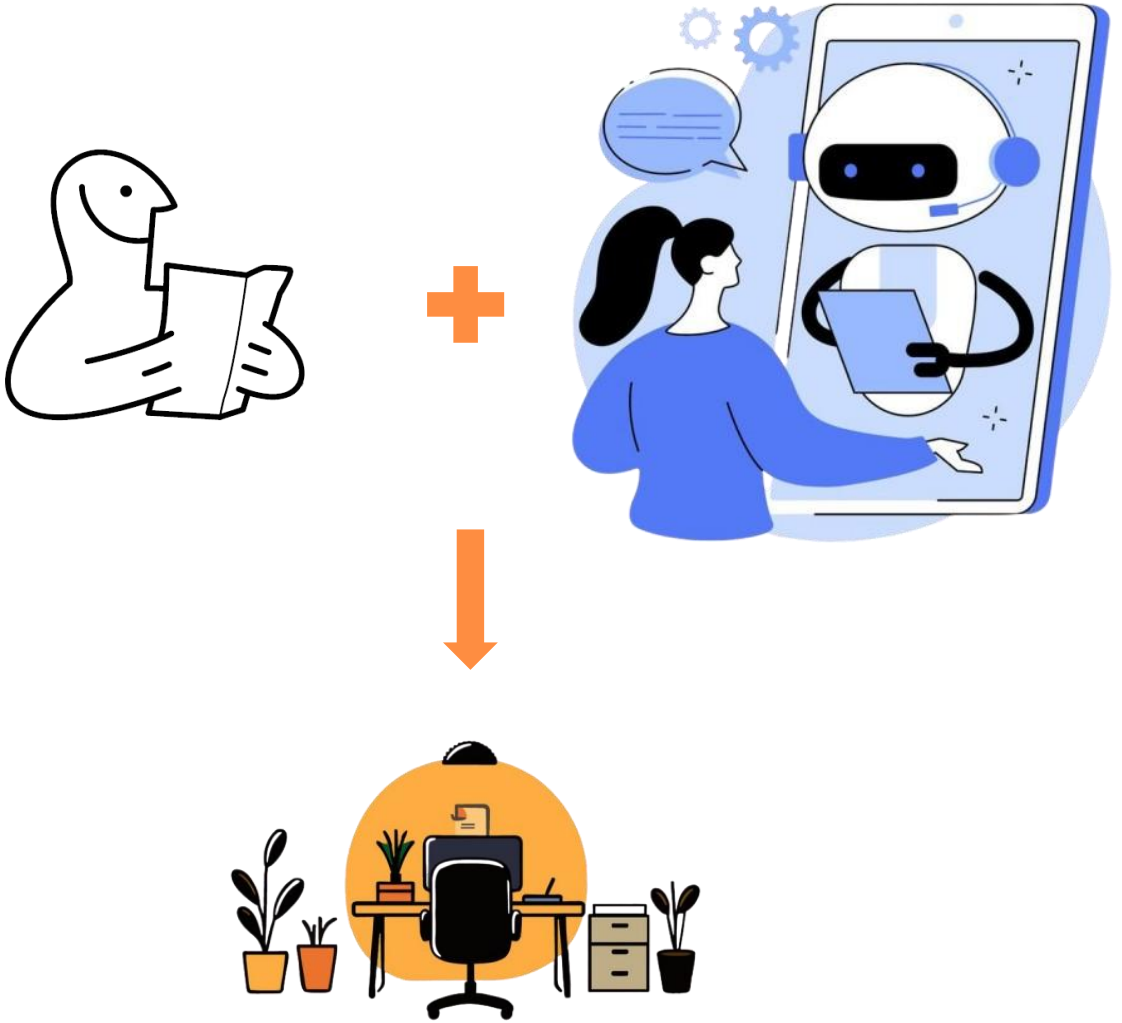
26/11/2025

Capgemini

Systems Engineering feels like sometimes……



Source: IKEA + Pinterest



Agenda

1. Introduction
2. AI as an enabler for systems engineers & architects
3. Example of AI for architecture
4. Conclusion

1 INTRODUCTION

1. Introduction

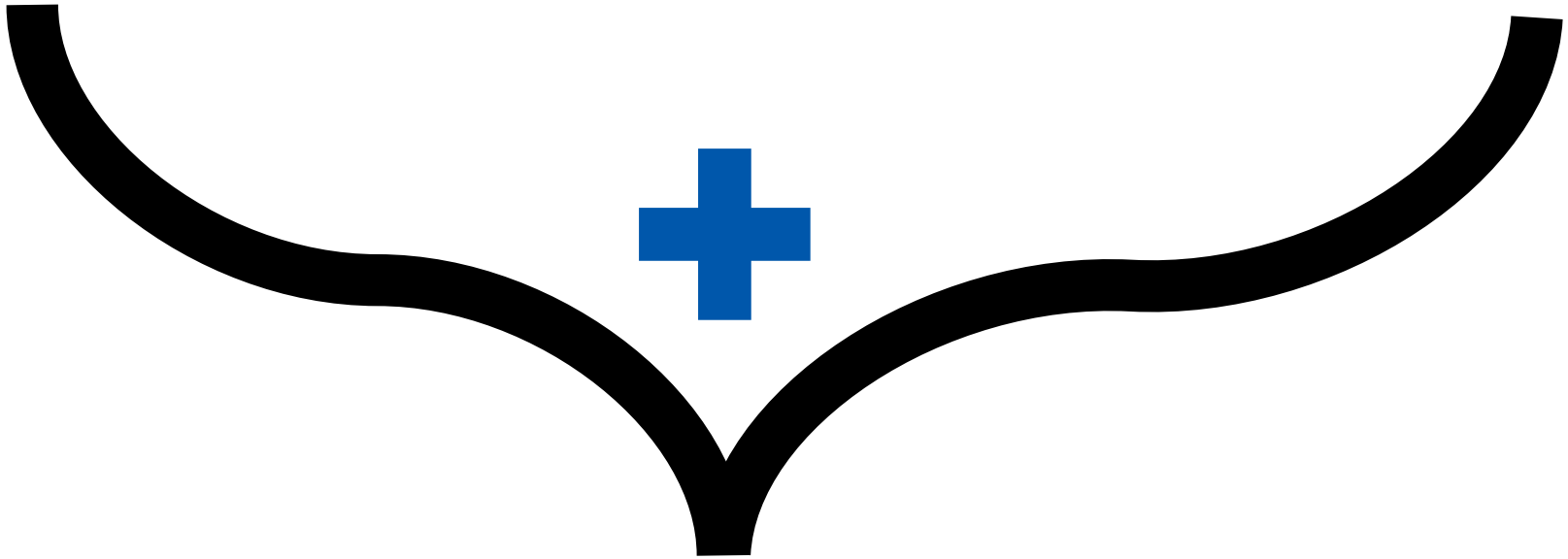
What is Generative AI?

Fondamental Models (FM)

A large pre-trained model (like GPT, Claude, Gemini, etc.) that has been trained on vast amounts of data to understand and generate human-like content (text, code, images, etc.).

Prompts & Instructions

The input provided by the user or another system, which guides the model to perform a specific task (e.g., “Write a summary,” “Generate code,” “Explain this concept,” etc.).



GEN AI

Generative AI (GenAI) refers to a type of artificial intelligence that can create **new content**, such as text, images, audio, code, or video by learning patterns from **existing data**.

🧠 **Models** + 💬 **Prompts** = ✨ **New content**

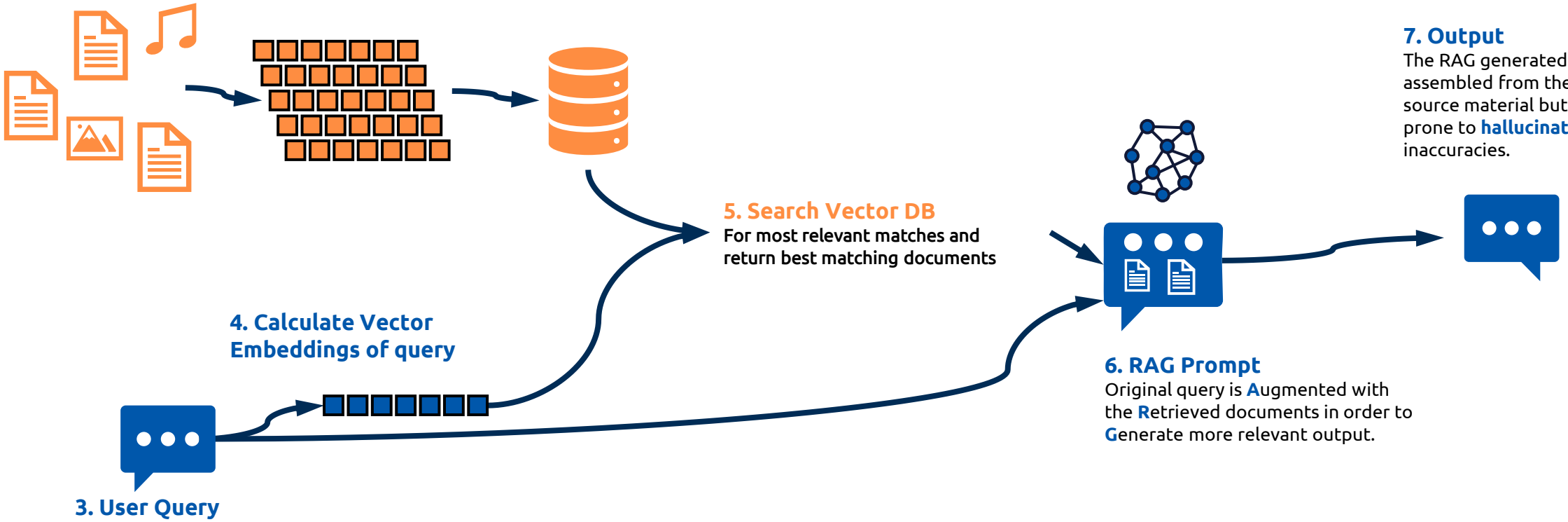
1. Introduction

Retrival Augented Generation (RAG) model

Retrieval-Augmented Generation (RAG) is a method that allows **customizing a base model without fine-tuning** by relying on updated or specialized data, rather than solely on the internal knowledge of the base model.

1. Calculate Vector Embeddings
Numerical representations that encode the semantic properties of the documents

2. Store in Vector Database
A special database designed for fast comparison of embeddings



3. User Query

4. Calculate Vector Embeddings of query

5. Search Vector DB
For most relevant matches and return best matching documents

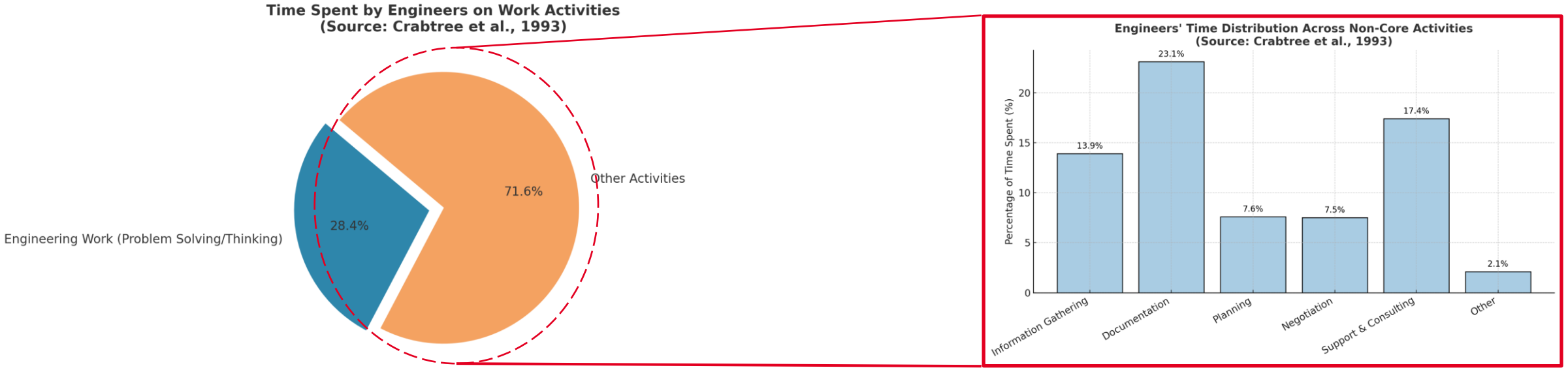
6. RAG Prompt
Original query is **A**ugmented with the **R**etrieved documents in order to **G**enerate more relevant output.

7. Output
The RAG generated output will be assembled from the matching source material but is still just as prone to **hallucination** and inaccuracies.

Source : Referential architecture

1. Introduction

Paper

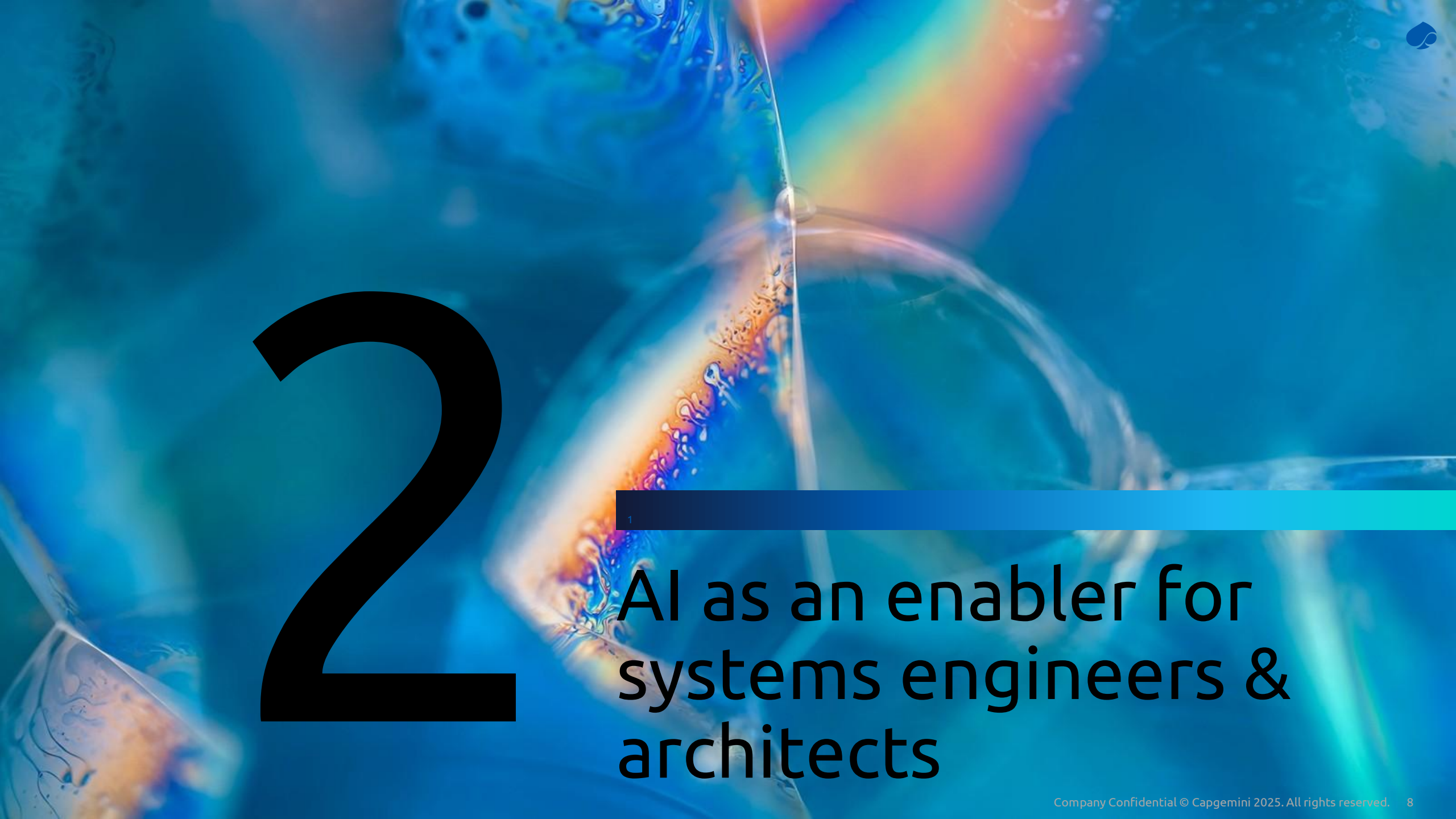


> Multiple recent studies has shown 60 – 70% of engineering time is consumed by documentation – adjacent work: writing requirements, generating reports, or just simply searching for information.

Report 1 GleanReport2024

Report 2 IDCReport2024

This project targets exactly this slice with AI assistance.



2

AI as an enabler for systems engineers & architects

2. AI as an enabler for systems engineers & architects

Objective, method & constraints

Objectives

Design and **develop** artificial intelligence **models** to meet the **operational needs** of engineers and system architects (based on INCOSE / ISO15288).

Method

1. Develop a structured **knowledge base** from engineers' insights.
2. Conduct a **comprehensive review of existing AI applications** inside & outside Capgemini Engineering.
3. **Practical Integration** of AI in systems engineering activities.

Constraints

1. Ensure the **security and confidentiality** of customer data.
2. Ensure the **reliability of results** produced by AI models (limiting hallucinations)
3. Not being bothered by **technical limitations** (token limitation, fundamental models' legacy,…)

2. AI as an enabler for systems engineers & architects

Systems Engineers & Architects' insight

- Excessive documentation
- Legacy Tools Inefficiencies[1][2]
- Communication gap between multiple stakeholders*
- Difficult to measure & Justify

AI can help mitigate these challenges [3]

- Large datasets are slow to manage
- Data overload : multiple formats
- Traceability matrix maintenance [1][2]
- Compliance checklist validation [1][2]

[1] https://www.iese.fraunhofer.de/content/dam/iese/publication/systems-engineering-challanges-and-best-practies-fraunhofer-iese.pdf

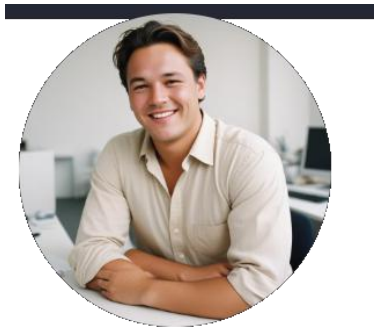
[2] P. Mäder, P. L. Jones, Y. Zhang and J. Cleland-Huang, "Strategic Traceability for Safety-Critical Projects," in IEEE Software, vol. 30, no. 3, pp. 58-66, May-June 2013, doi: 10.1109/MS.2013.60.

[3] John, Alan & Oosthuizen, Rudolph & Fanta, Getnet. (2024). Artificial Intelligence Integration in Systems Engineering: Navigating Opportunities and Risks Across The System Lifecycle. 10.52202/078172-0039.

2. AI as an enabler for systems engineers & architects

S.A.M : (*Systems engineering Assistant for Methods)*

Contact person :- Florent Brunel



- Based on the **Capgemini Generative Engine**
- LLM > anthropic.**claude**-3-5-sonnets
- RAG (~1000 documents)
- Knowledge management assistant

International Norms & Standards

INCOSE
(International Council On Systems Engineering)
SE Handbook, SE BoK , Several books, INSIGHT magazines, Newsletters

ISO
ISO15288, etc.

Misc
***NASA** SE Handbook, CESAM pocket guide, **OMG**-SysML, Acadia method, **PhD Thesis**…*

IREB
(International Requirement Engineering Board)
Handbook

INCOSE French Chapter (in French)
practical guides, SE Handbook, …

PPI
(Project Performance International)
newsletters

Training materials

Capgemini internal training materials
SE, Funct Archi, SysML, MBSE, Syst Thinking, …

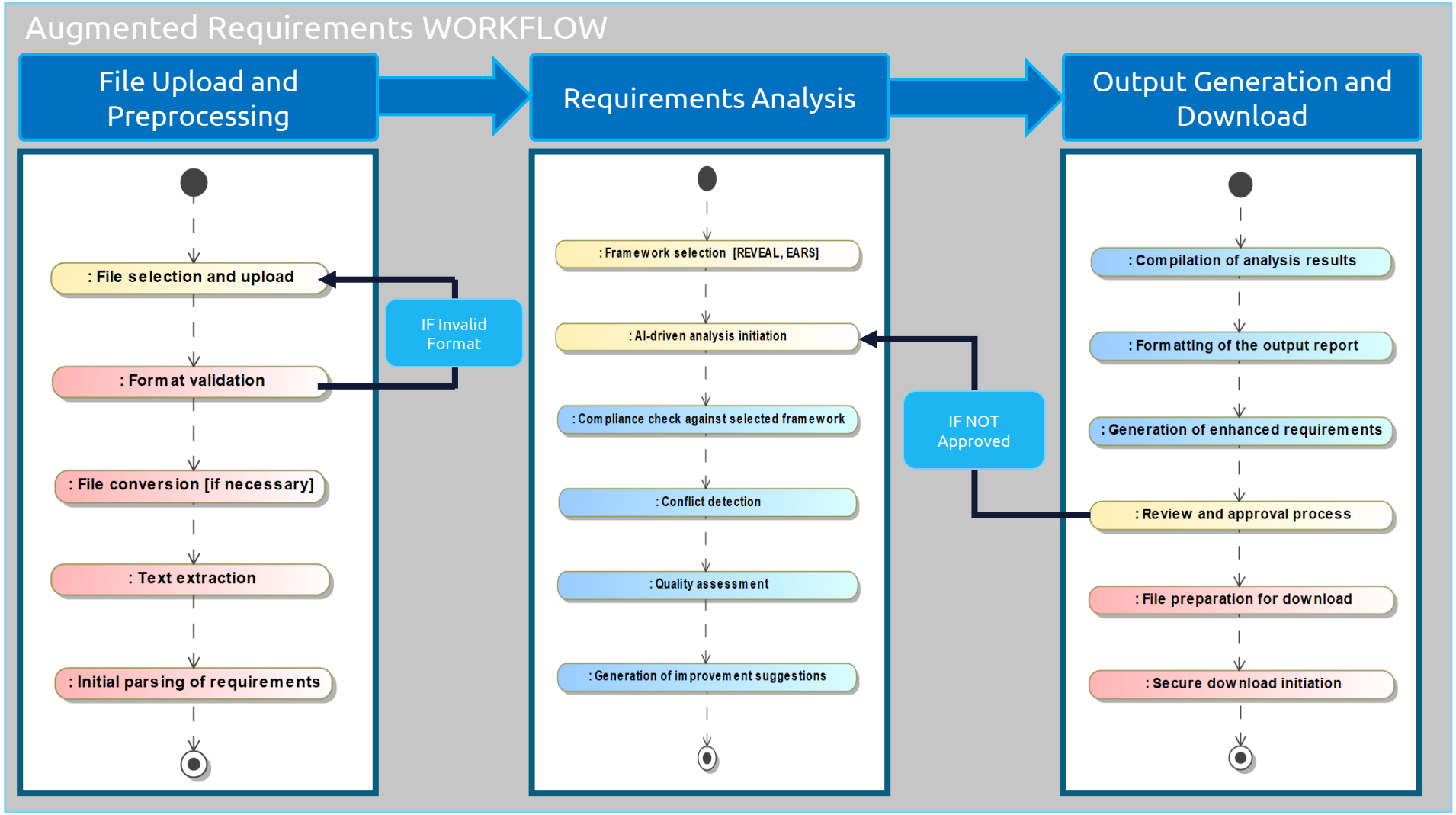
MIT Open Sources training materials

More Info: SAM & Knowledge Base

2. AI as an enabler for systems engineers & architects

Requirement COPILOT

- Python Based development
- Can be deployed for client project
- On- Going → Got funding to expand



Contact person :- Jake Brown & Scott Reid

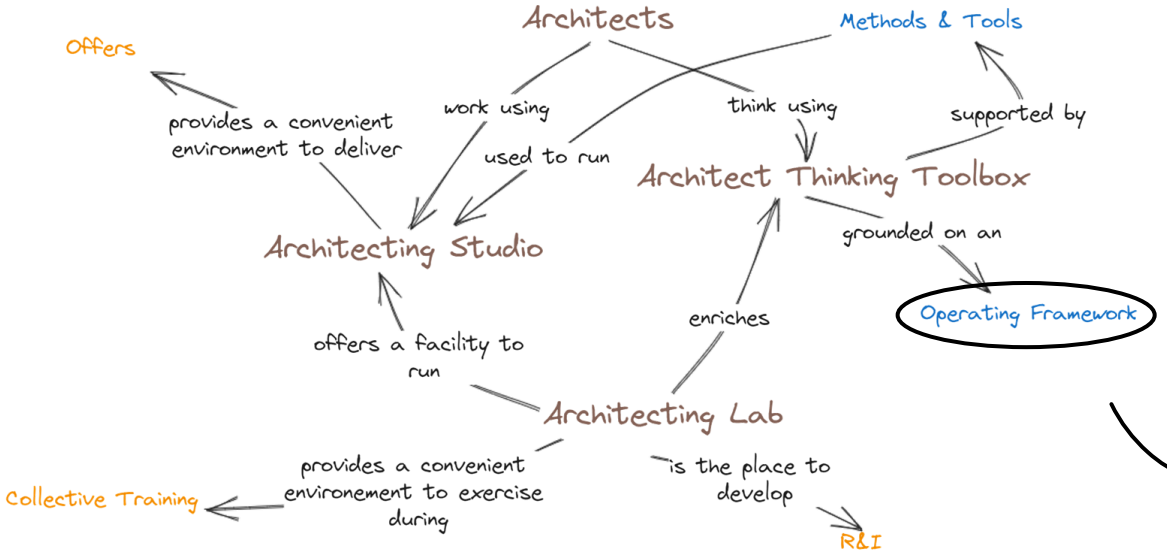
More Info: [Requirement Copilot]

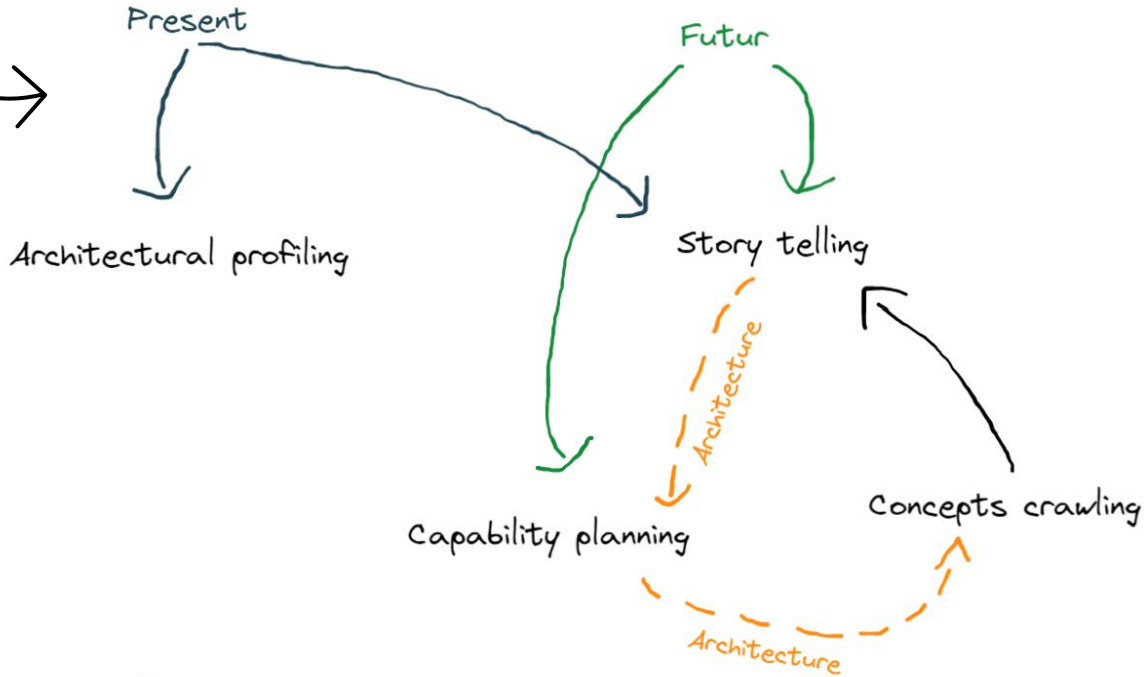
3

Example of AI for architecture

3.1 - Our new paradigm proposal

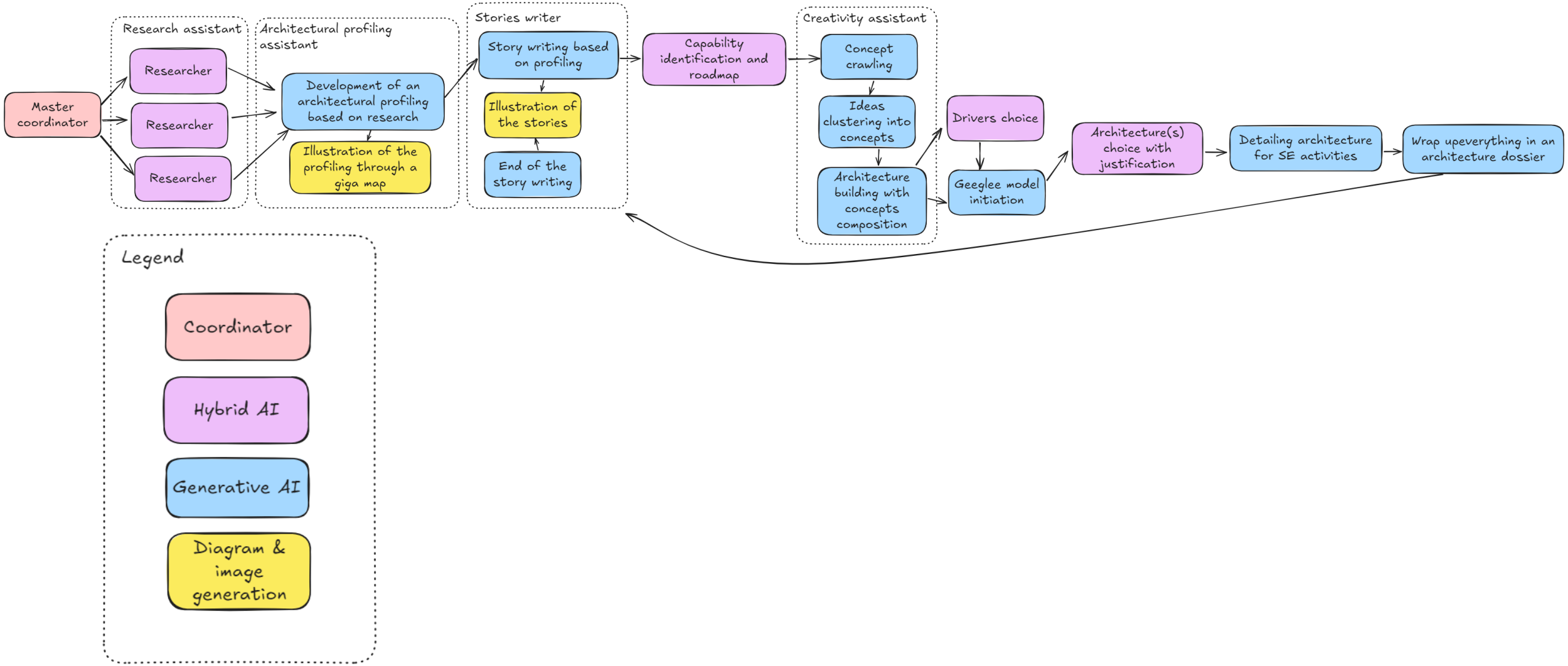
A glimpse at our operating Framework





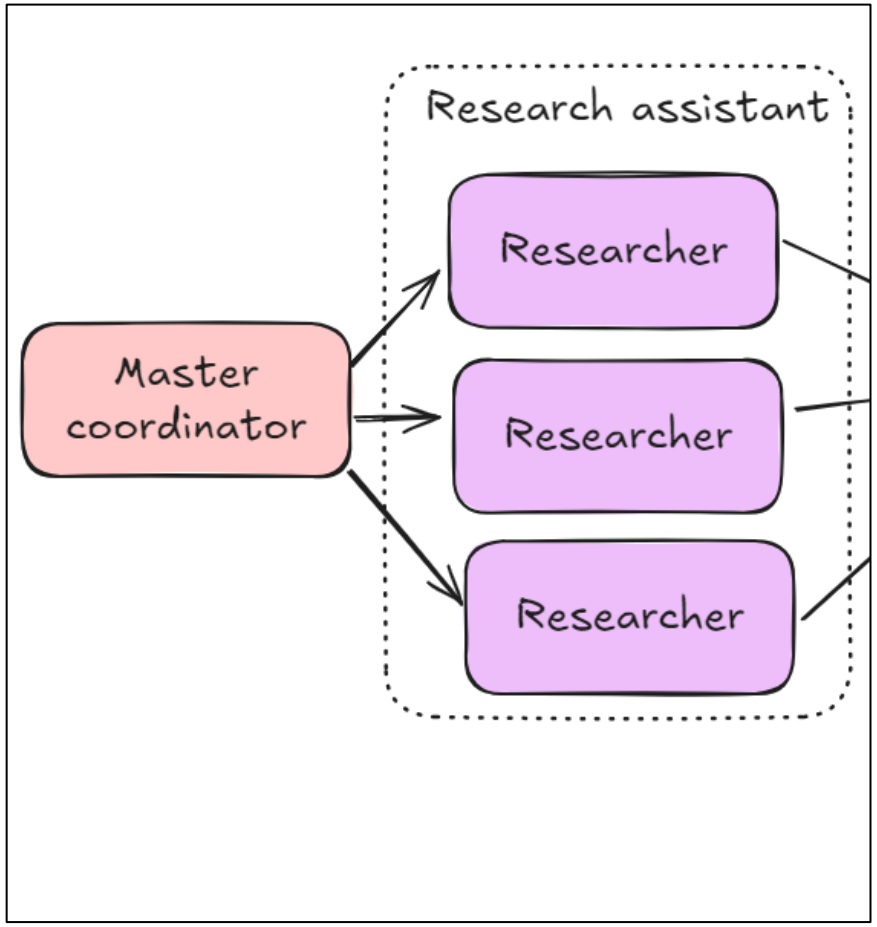
3.2 - How to enhance our approach with AI?

Agentic AI



3.2 - How to enhance our approach with AI?

Agentic AI – Architectural profiling



Objective: Build a sourced, reliable and verified database

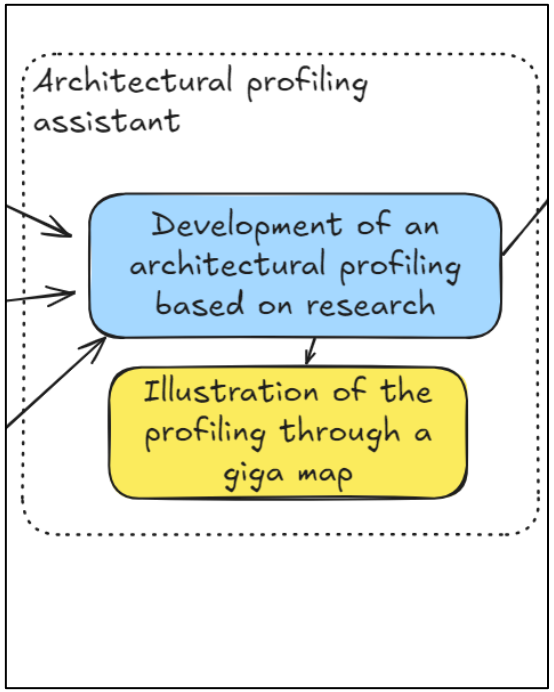
Example: Wolfram Alpha x Chat GPT

Need: Complex ecosystems, difficult for humans to understand. Computational, hybrid AI

Status: Lack of hybrid AI, handmade research

3.2 - How to enhance our approach with AI?

Agentic AI – architectural profiling



Objective: To build an architectural profiling

Example: Copilot with an enriched RAG with the documents grouped together during the search phase

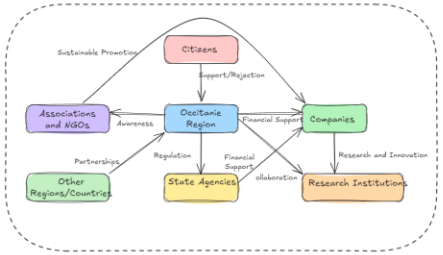
Need: Complex ecosystems, difficult for humans to understand.
Generative AI to synthesize and illustrate

Status: First example on the hydrogen ecosystem
Lack of data

3.2 - How to enhance our approach with AI?

Agentic AI – architectural profiling

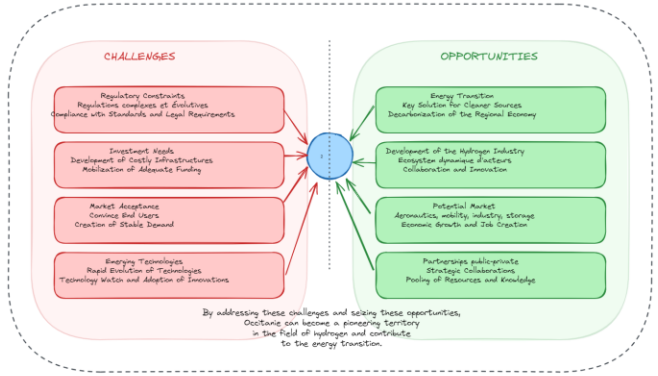
STAKEHOLDERS MAP



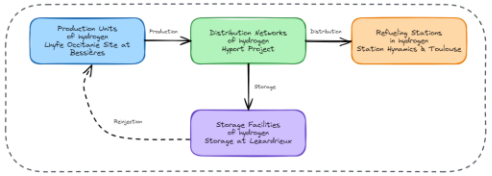
RISKS AND CONSTRAINTS

OBJECTIVES

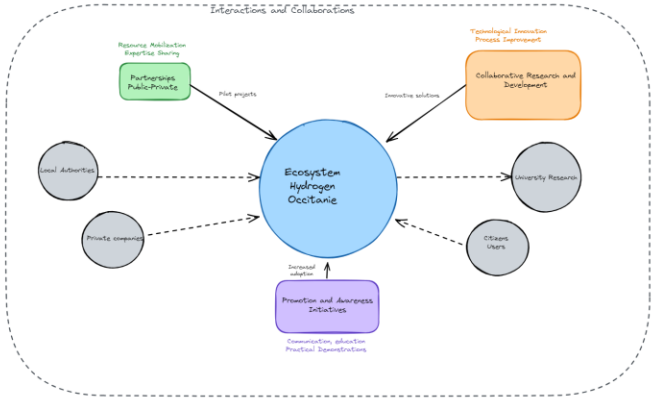
CHALLENGES AND OPPORTUNITIES



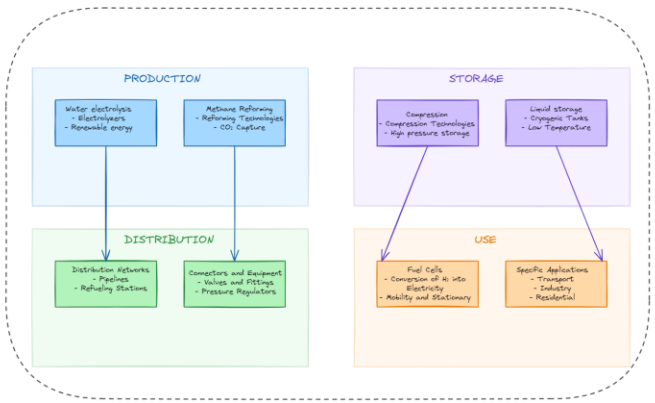
EXISTING INFRASTRUCTURES



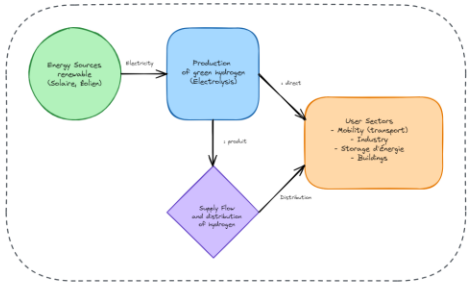
INTERACTIONS



KEY TECHNOLOGIES

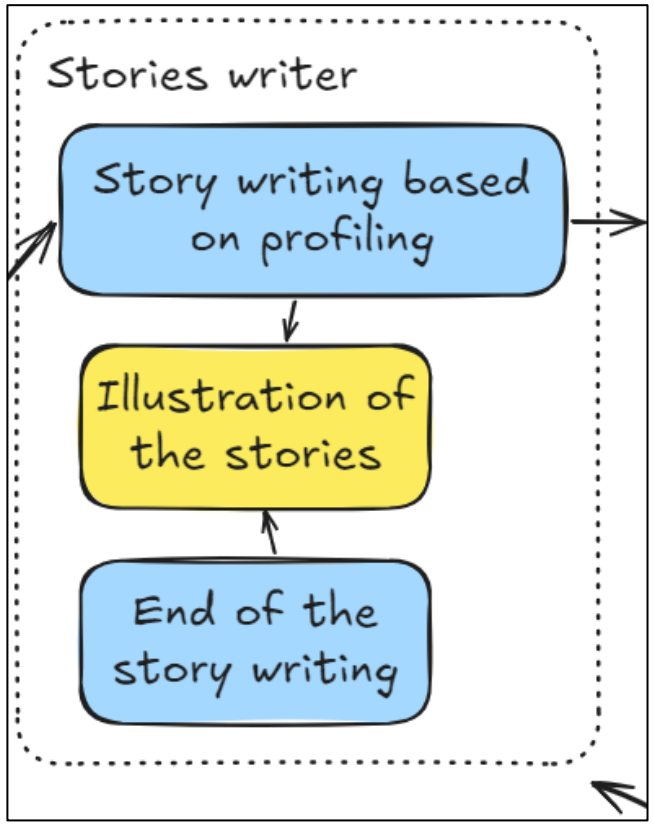


Energy flow



3.2 - How to enhance our approach with AI?

Agentic AI – Story telling



Objective: To build several stories in the ecosystem, embodied by characters. Finish writing the stories according to the chosen architecture

Need: To convey value, identify use cases and capabilities, need to write stories

Example: Copilot with an enriched RAG with the documents grouped during the search phase

Status: First example carried out on the hydrogen ecosystem, quite successful

3.2 - How to enhance our approach with AI?

Agentic AI – Story telling

The Technological Challenge of Hydrogen

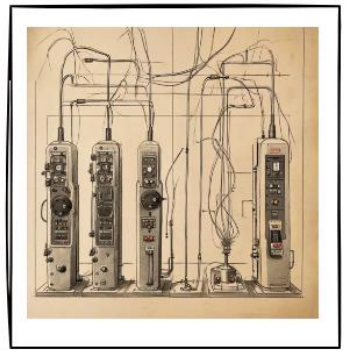
1. Exposition

In the Occitanie region of southern France, Emma, a dedicated 30-year-old engineer, and her colleague Paul, a seasoned 35-year-old technician, are working together on an innovative project to deploy a new hydrogen production technology in Carcassonne.
Their mission:
To promote green hydrogen as a sustainable energy alternative for the region.

2. Complication

As work progresses on the project, Emma and Paul face a major obstacle: an unexpected malfunction in the electrolyzer, the key equipment used for hydrogen production.
This unforeseen technical issue compromises the facility's ability to produce hydrogen efficiently and reliably.
In addition, environmental challenges related to the management of waste and by-products from the electrolyzer are emerging, threatening the overall sustainability of the initiative.

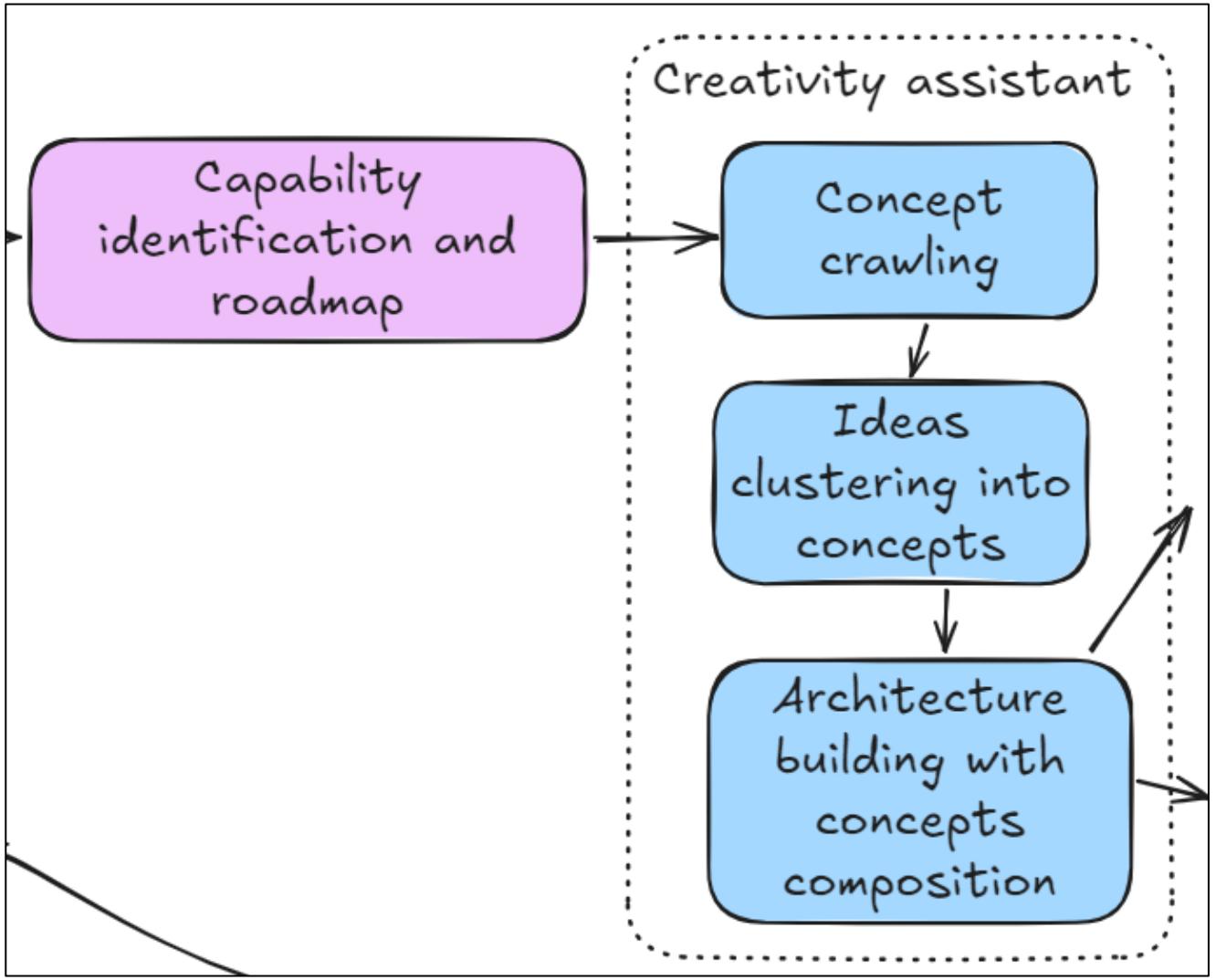
3. Climax



As the commissioning date of the facility approaches, Emma and Paul find themselves facing a crucial decision.
The persistent malfunction of the electrolyzer threatens the viability of the project and raises concerns about its scalability.
Moreover, unresolved environmental issues—particularly those related to waste and by-product management—are causing growing unease within the local community, calling into question the social acceptance of hydrogen technology.
Emma and Paul must now devise innovative solutions to overcome these technical and environmental challenges and ensure the success of their initiative.

3.2 - How to enhance our approach with AI?

Agentic AI – Concept crawling



Objective: Based on the stories, identify the capabilities to be developed.
For each capacity, explore the concepts that can make it possible, cluster these ideas into architectural bricks

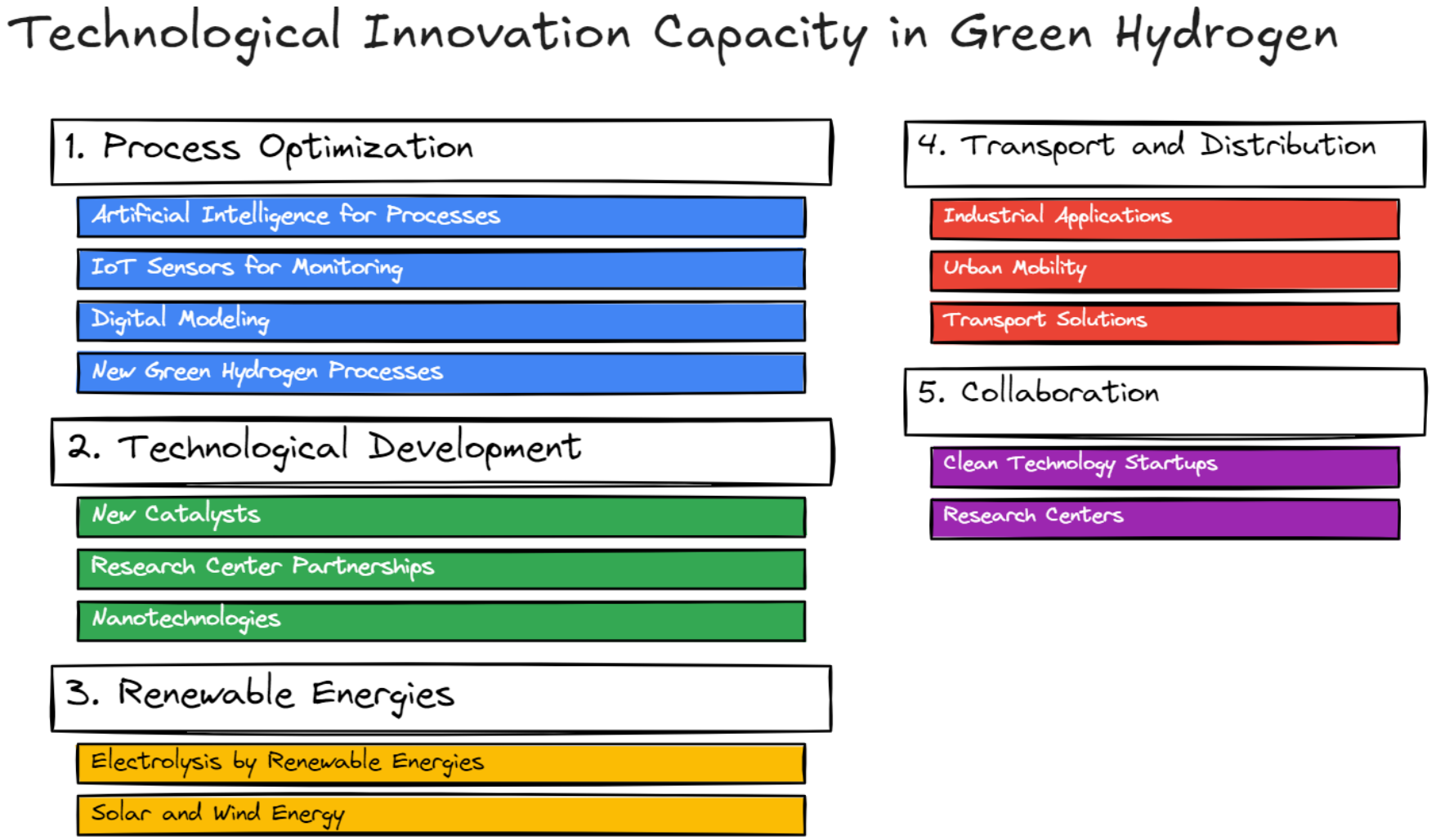
Need: Use AI to improve creativity in the search for concepts

Example: Copilot with an enriched RAG with the documents grouped during the search phase and the AI-generated stories

Status: Capabilities and concepts are too generic and do not necessarily include technical solutions.
A database with sets of concepts must be created (e.g. biomimicry pattern)

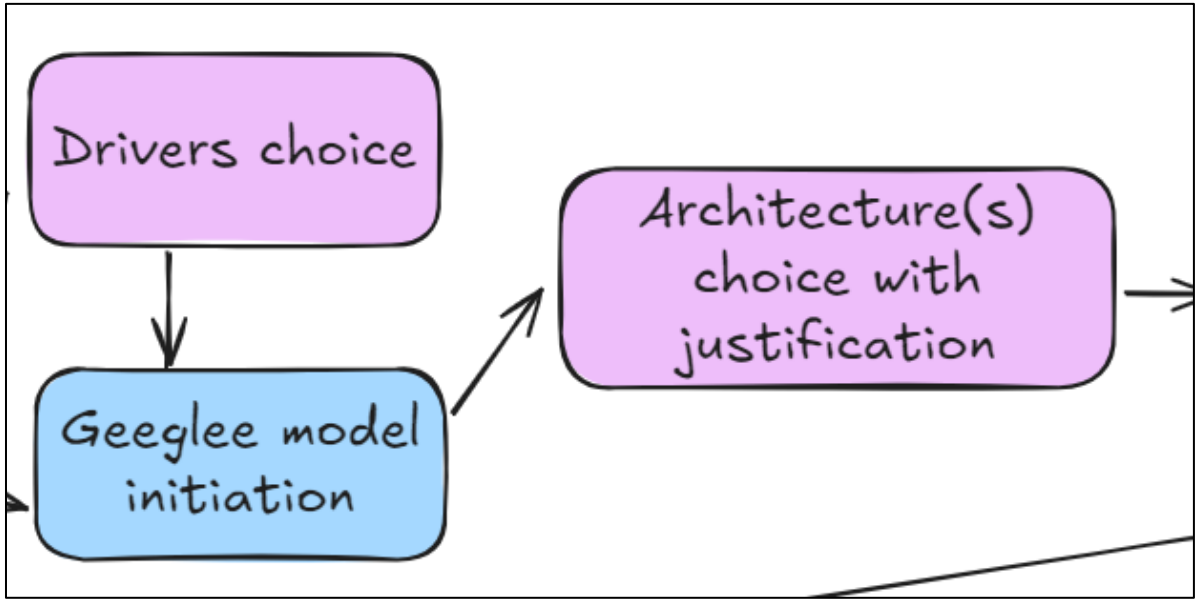
3.2 - How to enhance our approach with AI?

Agentic AI – Concept Crawling



3.2 - How to enhance our approach with AI?

Agentic AI – Architectures exploration



Objective: To build a Geeglee model to use combinatorics to explore architectures

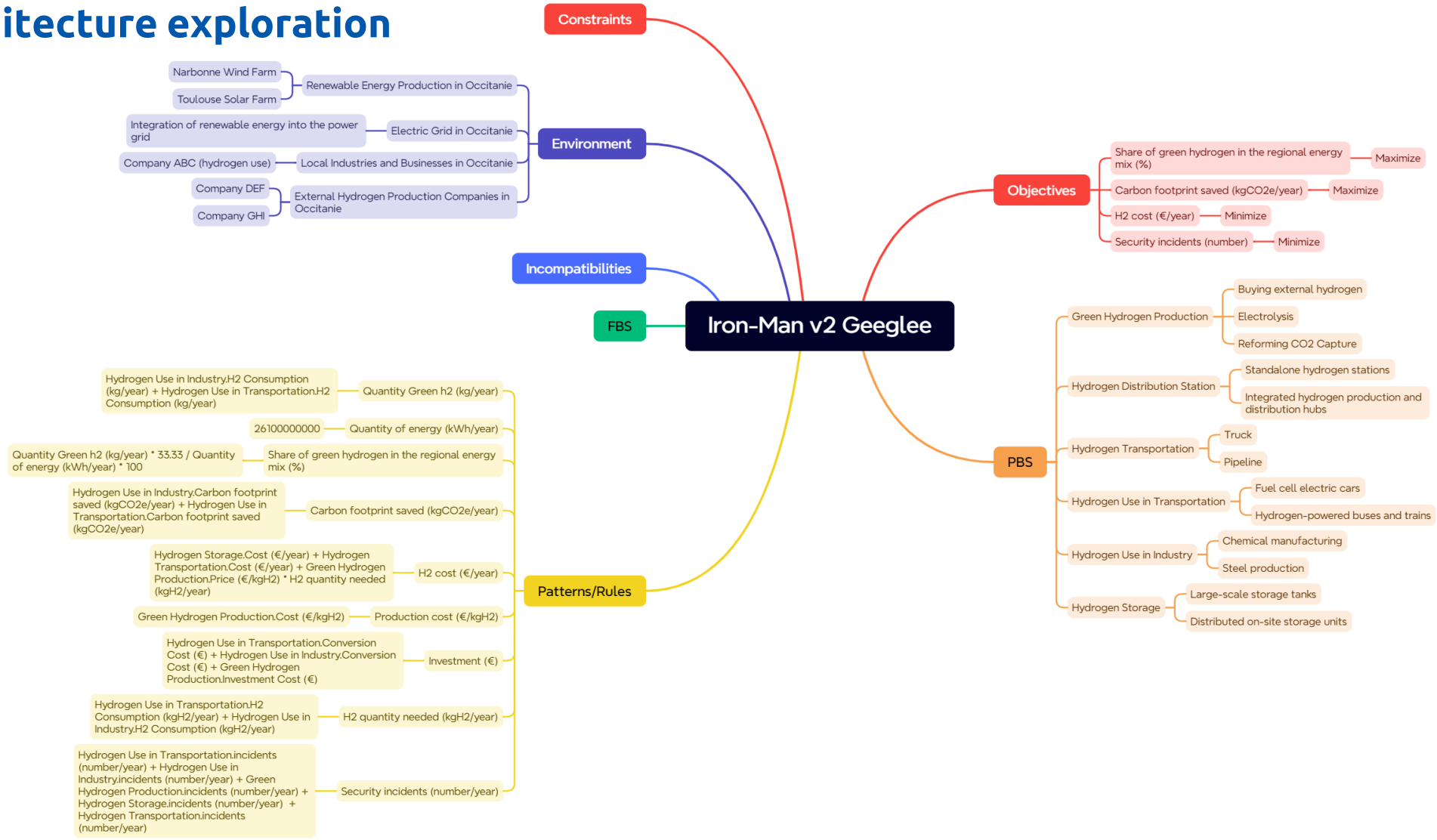
Example: Copilot with a rich RAG with the Geeglee framework, a sample concept map and architectures

Need: Use AI to initiate a Geeglee model from different architectures and from a concept map

Status: Geeglee model is well initiated

3.2 - How to enhance our approach with AI?

Agentic AI – Architecture exploration



Presented with xmind

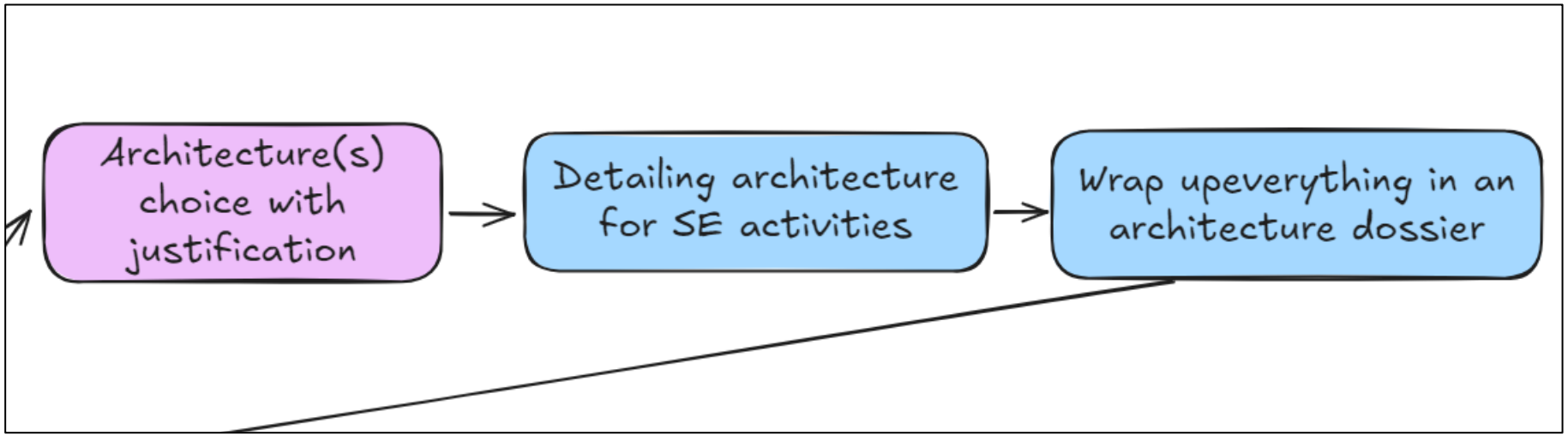
3.2 - How to enhance our approach with AI?

Agentic AI – Architecture exploration

	Electric Grid in Occitanie			External Hydrogen Production C…		Local Industrie…	Renewable Energy Production i…	
	Current energy mix	Future energy mix with…	Future energy mix with…	Company DEF	Company GHI	Company ABC (hydrog…	Narbonne Wind Farm	Toulouse Solar Farm
Carbon footprint saved…	99	99	30					
H2 Consumption (kgH…						500 000		
Investment Cost (€)							1 500 000	1 300 000
Part of renewable ener…	80	100	0					
Price (€/kgH2)				10	12			
Production capacity (k…				2 000 000	10 000 000			

3.2 - How to enhance our approach with AI?

Agentic AI – Decisions taking



Objective: To take decisions to build an architecture

Need: Use AI to synthesis work about architecture

Example: Copilot with a rich RAG with the Geeglee framework, ecosystem data, and architectures.

Status: Not completed for the moment

4 Perspectives and feedbacks

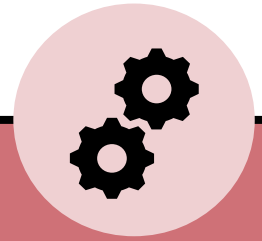
4 Perspectives and feedbacks

Data Privacy

- Workspaces dedicated to a project or a client must be created to refine the answers and ensure data confidentiality
- **Guarantee the confidentiality of the data used.**

Reliability of results

- Risk of hallucinations of the models (even for RAG)
- Lack of criteria to verify the reliability of generated content.
- Need to keep a human in the loop
- The prompt is one of the foundations of AI for the SE



Technical limitations

- Models that are too high level or too specific.
- GEP constraints: token limits, legacy fundamental models.
- Difficulty generating MBSE diagrams due to data and intellectual property constraints.

RSE Factors

- The adoption of AI tools by engineers.
- The environmental impact of generative AI models

Perspectives

- Hybrid AI
- Improve methods with ECSE and SEA


Questions ?

Merci !

Make it real.

Capgemini