From MBSE to Digital Engineering: architecture as a backbone

CESAMES

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Introduction

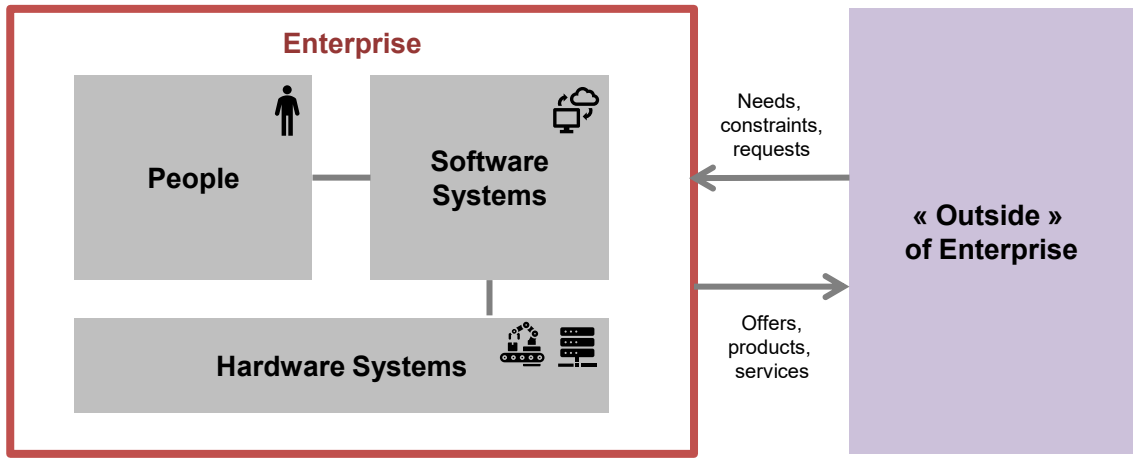
The increasing **complexity** of the products developed by industrial companies **reaches** the level of the company and the **means implemented**, such as **Digital Engineering**. The management of this complexity cannot be solved only **technically**: it is an **architectural** problem to be considered as a whole **human** and **technical**.

Increasing complexity of **products**

New **technologies**, **economic** and **geopolitical** constraints are pushing the systems produced to integrate ever more **complexity**

Complexity that spreads across the **organisation resources**

Organizations are deploying highly **integrated capabilities** and **technologies**, such as **digital engineering**, to address **deployment** complexities and **reduced cycle times**



The need for **entreprise architecture** to build this transition

Integrating **tools** and **models** is a very complex challenge. **Standards** such as **SysML v2** and new technologies such as **AI** will not be enough to solve **alignment** problems: **architects** within companies are needed to think about this **integration**

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1.1 Engineering and a paradigm shift

Industries are facing both **increasing** complexity and **shrinking** cycles

The systems produced incorporate many **dimensions**

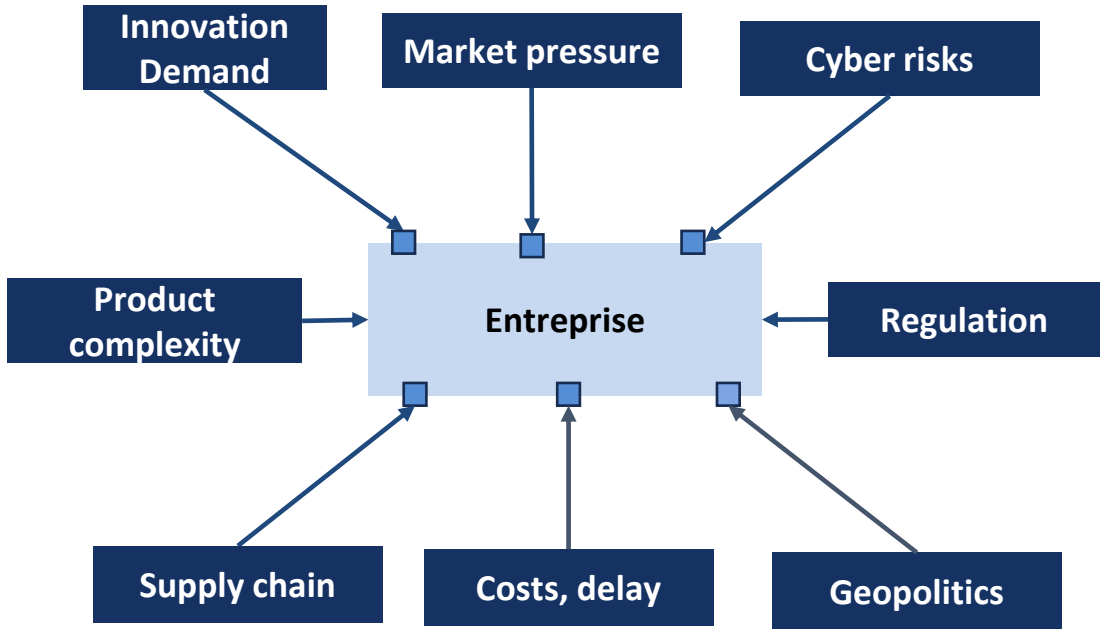
- **Digitization** of systems
- **Connectivity** (embedded, cloud, IoT, OT, etc.)
- **Cyber** constraints
- **AI** Integration
- **Scalability** and **resilience** (product line logic, innovation, sustainability, etc.)

Development **cycles** are more **constrained**

- **shorter**, because time to market is becoming central in a highly competitive world
- more **iterative**, because you have to include a lot of innovation
- More **uncertain**, because the market is changing quickly and you have to be agile
- Constrained costs (RC and NRC) as the global economy slows down

Organizations are integrated into complex **ecosystems**:

- broad **economic ecosystems** and **extended entreprise**
- **Multi-tier** product architectures
- **Globalized** supply chains



1.2 The emergence of digital engineering

Digital engineering aims to introduce a **digital thread** to **accelerate** development cycles and gain **agility**

1960 Document Engineering

Document-centric approach
Dominant office tools (Word, Excel, etc.)
1990 – Creation of INCOSE

2005 : Introduction of MBSE

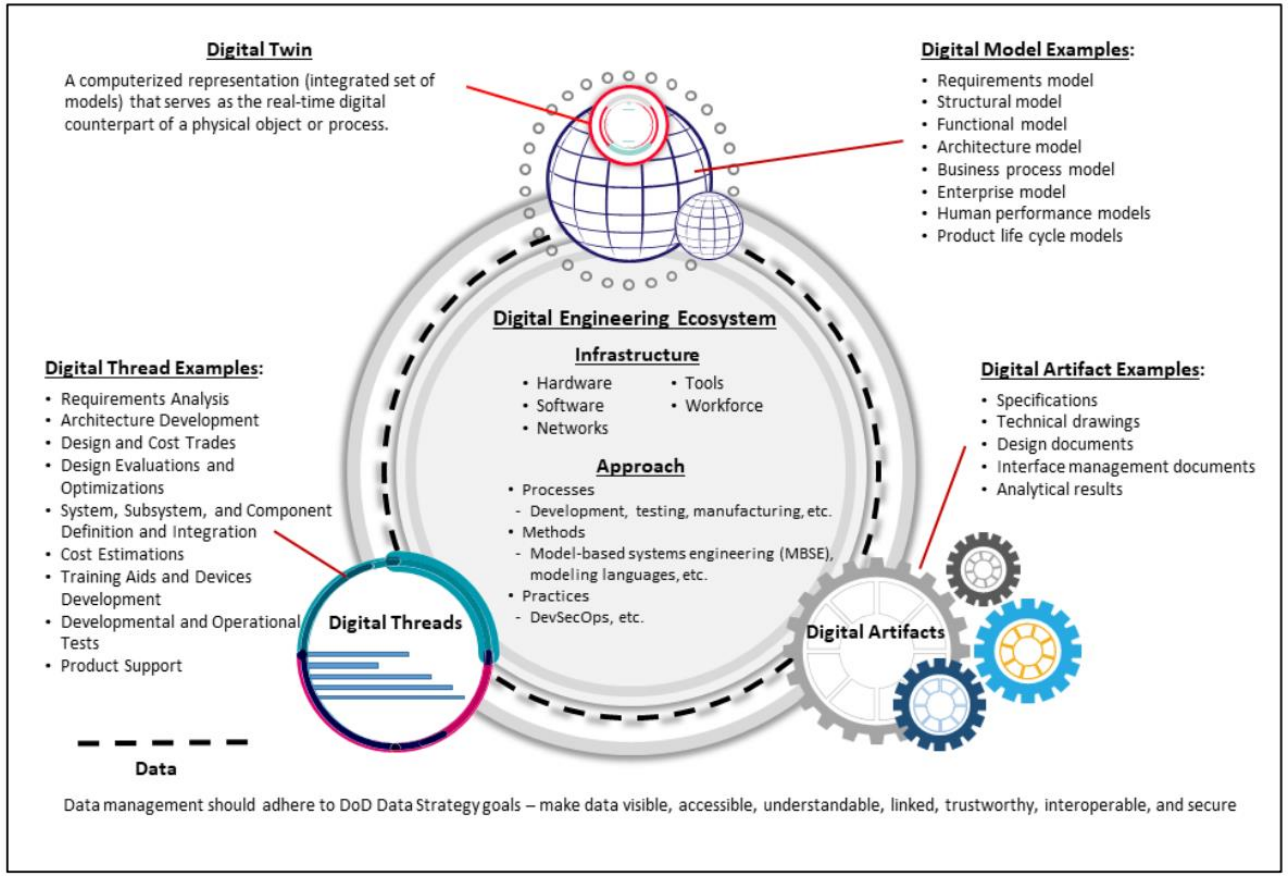
2007 - Standard SysML v1.0
~ 2010 Development of framework and methods (CESAM, Arcadia ...)
Transition from document to Models

2018 : Introduction of Digital Engineering

2018 – Formalization of the concept by the US Department of Defense
Generalization of the notions of digital thread and interoperability between tools (PLM, ALM, MBSE, etc.)

2022 : Introduction of AI

Generative AI
Knowledge graphs – ontologies
Agentic AI and Automated Engineering



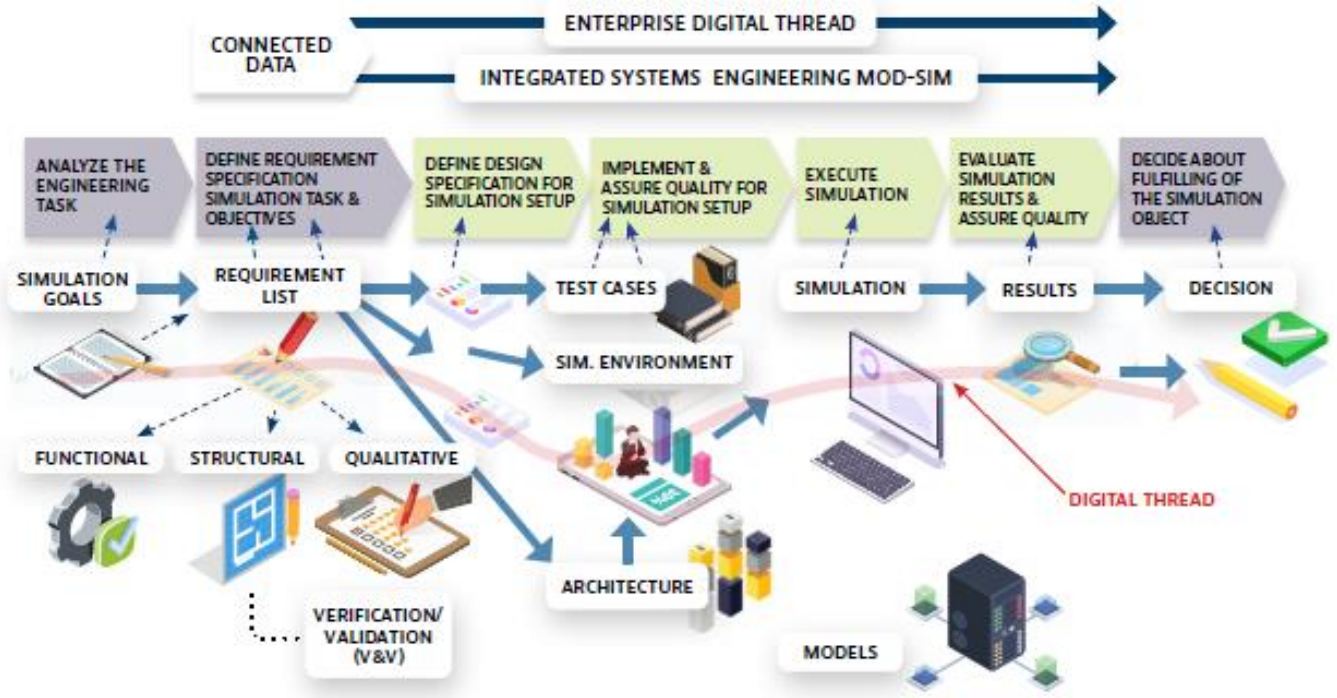
DoD Digital Engineering Framework

1.3 Model-Based as an essential pivot

The development of these **digital capabilities** relies on **Models** in general, and on **Model-Based System Engineering** in particular, as a pivot of **continuous integration** and real-time analytics: **MBSE** is becoming a **long-awaited pillar** of the integrated enterprise

Vision MBSE **INCOSE 2035**

- Unified integrated **MBSE-Systems Modeling and simulation** (SMS)
- **Integrated** into entrerprise digital thread
- **Integrated** AI Agents
- **Real time** system anomaly detection and virtual systems design updates
- **Integrated** life cycle management systems
- **Agile continuous integration**, build, validation and release



Vision INCOSE 2035 : future systems engineering is model based

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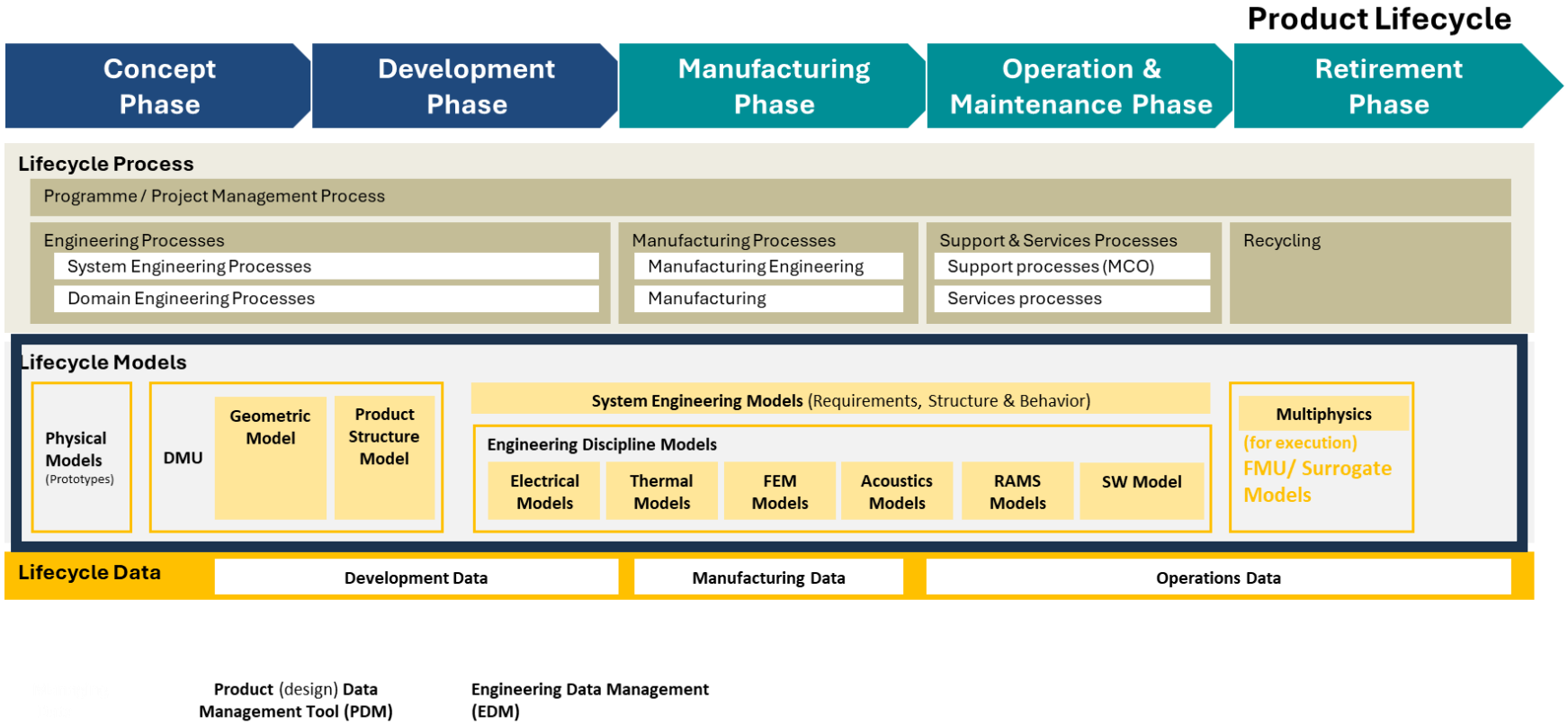
1. A fragmented territory
2. Insufficient standards
3. An MBSE still being deployed
4. Limited AI capabilities

2.1 The problem to be solved: model integration

The digital **reality** of **industrial companies** today is a very **fragmented** landscape of tools and models throughout the **product lifecycle**



There are many **specialised tools**

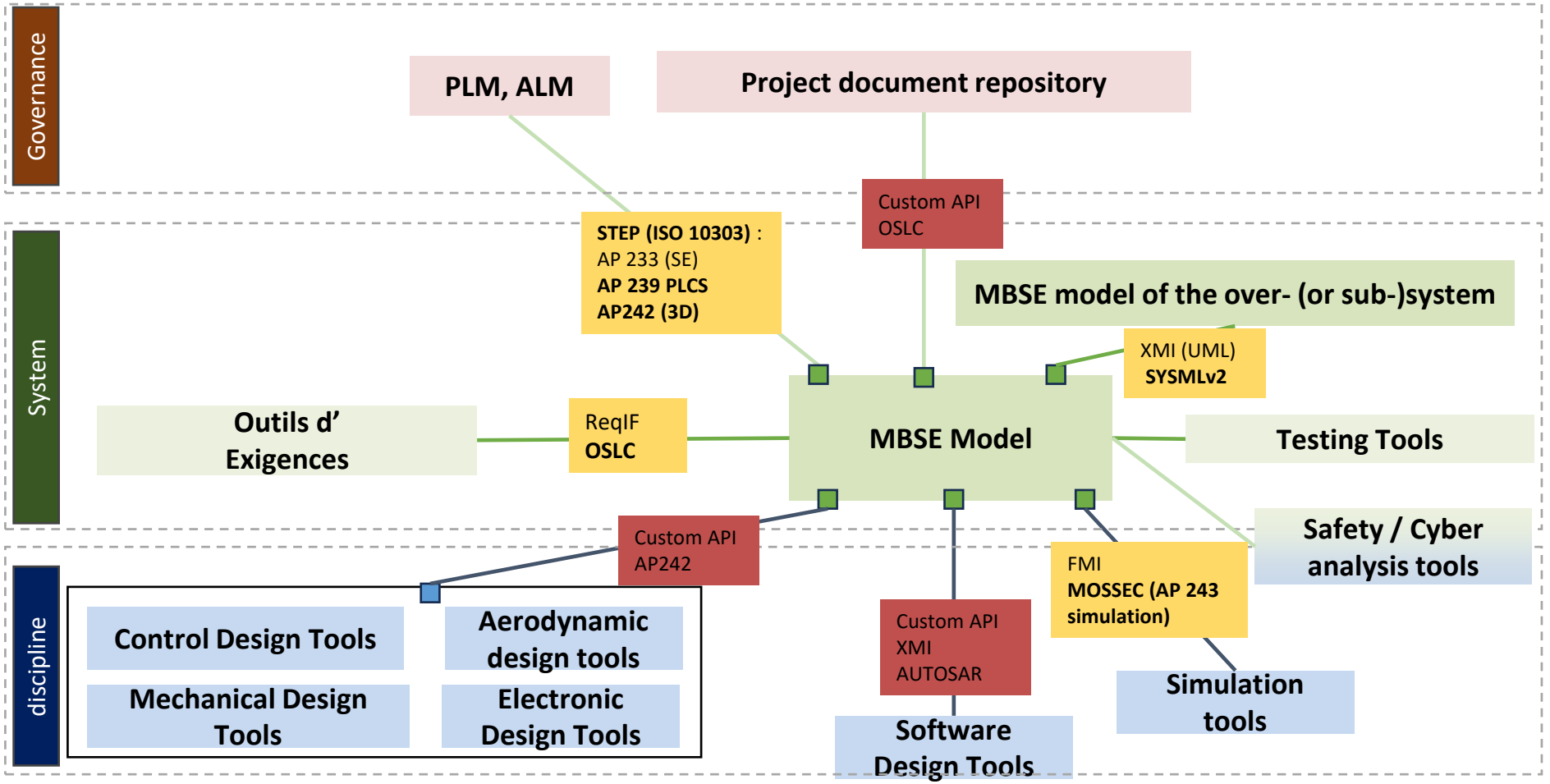
- PLM
- ALM
- MES
- MBSE
- Simulation
- Design
- Data Plateform …

Interoperability is limited

- Fragmented models
- Disconnected tools
- Implicit architectures
- Inconsistencies and lack of traceability

2.2 The multiplicity of standards and tools

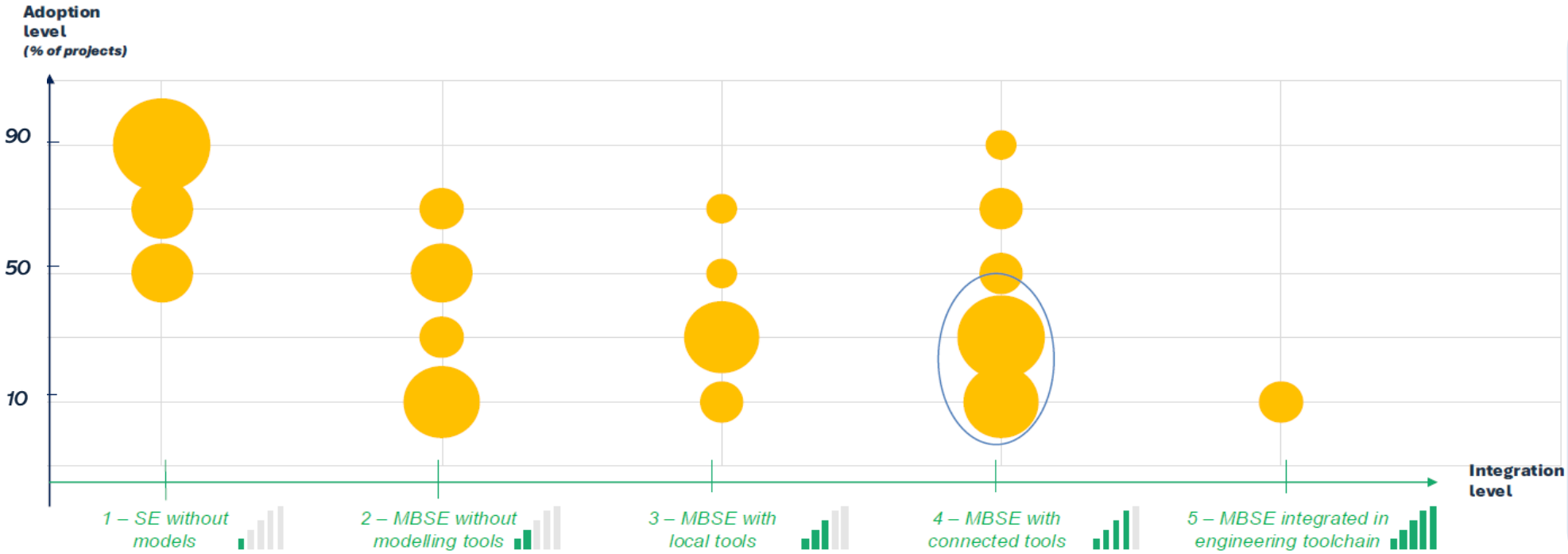
MBSE, the **theoretical pivot** for model integration, is faced with a multiplicity of **standards** and tools that limit their **real integration**



Despite continuous standardization efforts for more than 30 years (ISO STEP, OMG SysML, OASIS OSLC), standards remain **fragmented** and **evolving**. To date, they do not guarantee complete **semantic continuity** at the level of the **Digital Thread.**

2.3 An MBSE still in the deployment phase

The future development of these **capabilities** places **MBSE** at the **centre**, but its actual deployment in companies is still partial. The obstacles are **sociological** before they are **technical**



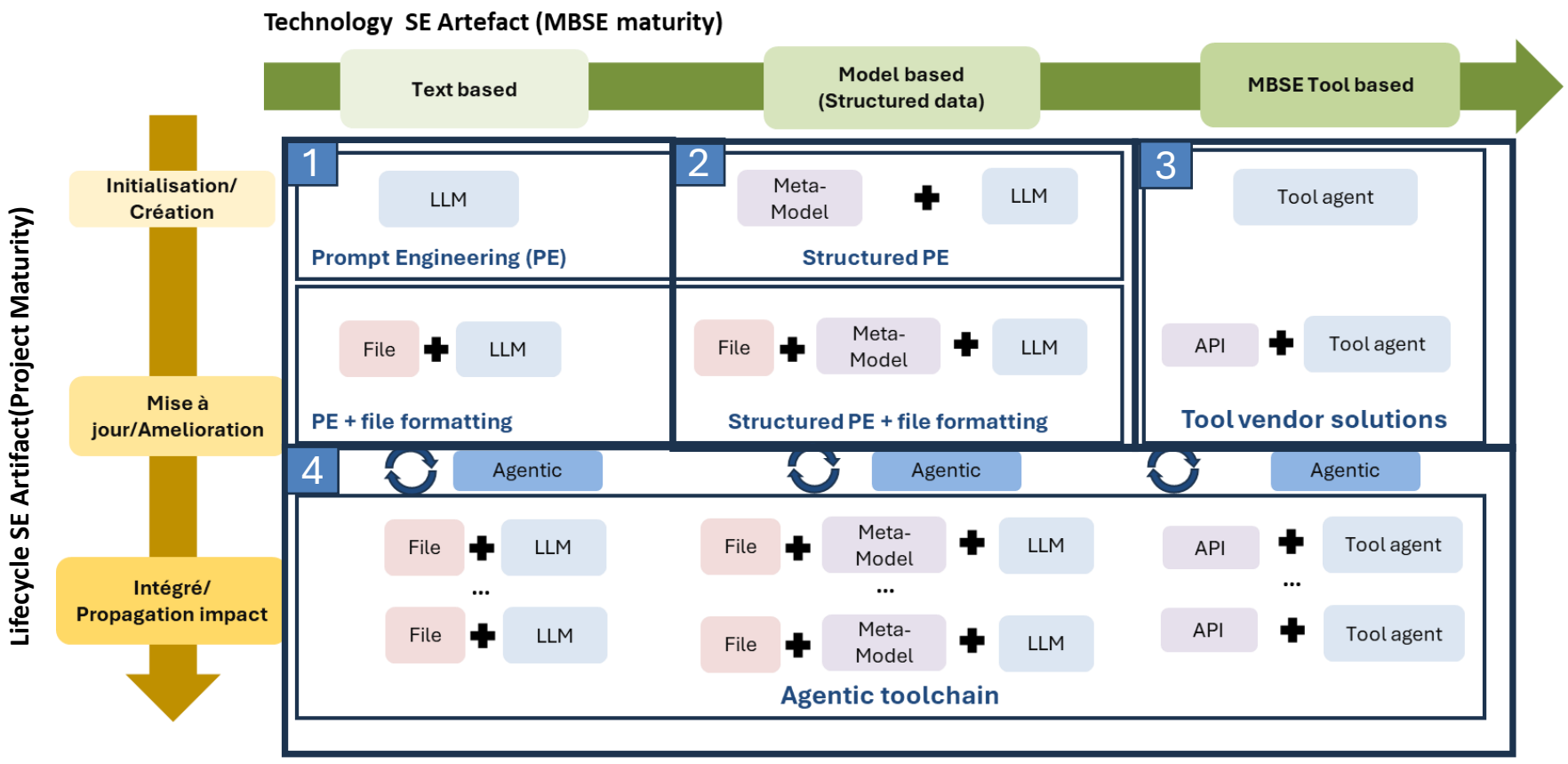
The three obstacles that emerge from the literature (Mc Dermott et al. 2020) and confirmed by the **CESAMES MBSE 2025** forum:

1) Cultural resistance
2) Skills and training
3) Lack of involved **sponsors**

CESAMES 2025 MBSE Observatory: adoption of the MBSE

2.4 Generative AI in support of the SE : a technology in maturation

The implementation and contributions of AI vary depending on the **maturity** of the **MBSE process** and the maturity of the **projects**. The lack of **data structure** and the difficulties of **automatic validation** still **limit** its effective deployment at **scale**



1. The absence of **Meta Model** makes artifact generation very **inconsistent** and is limited to **requirement engineering**

2. The use of **structured meta models** in **SysML v2** allows many use cases, limited today by the **deployment** of **SysML v2** and by the difficulty of **interfacing with unstructured files**

3. Tool vendors' solutions are limited by **interoperability issues** and the difficulty of **interfacing with unstructured files**

4. The **agentic manipulation** of data requires building a complete **digital thread** and structuring the **data as a whole.** This remains limited by the difficulty of introducing **robust automatic control tests for gen AI**

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3.1 The structuring role of enterprise architecture

To solve these difficulties of **integrating tools**, **technology** alone cannot be enough. It is an **architecture** topic to be dealt with at the **company level**: It is a complex cross-functional and **multi-domain problem**, which is based above all on the organization, interactions and collaboration between **actors**. These approaches still have **limited penetration** in the industry.

Integration fails because the **business and IT worlds** are evolving separately.

The business system carries the **objectives**, the **value** and the **needs**
The information system supports the **solutions and their implementation.**
Between the two, the link is often **limited** and the technical choices are **not justified** in terms of value.

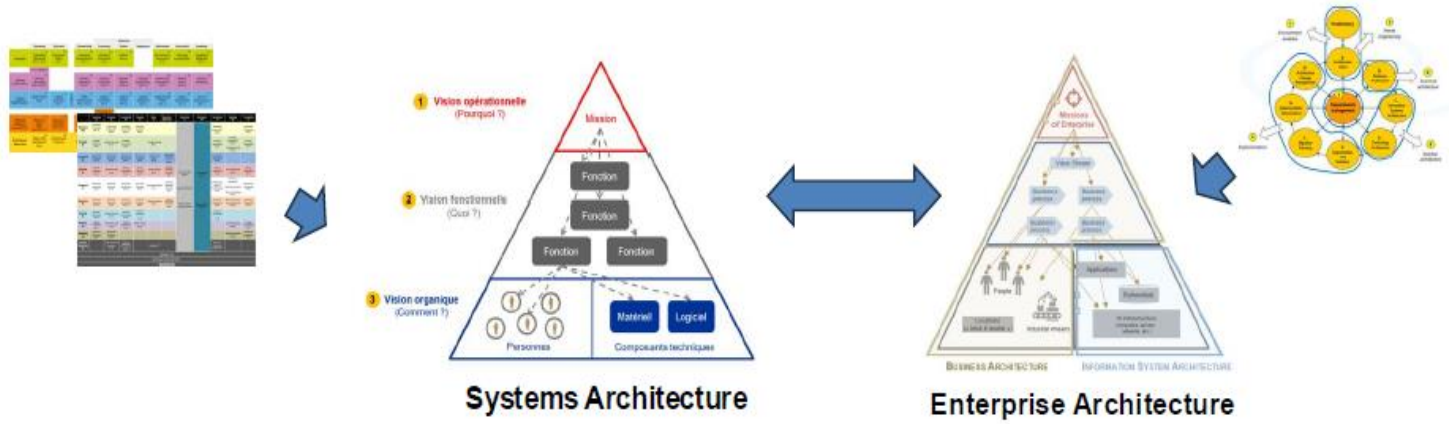
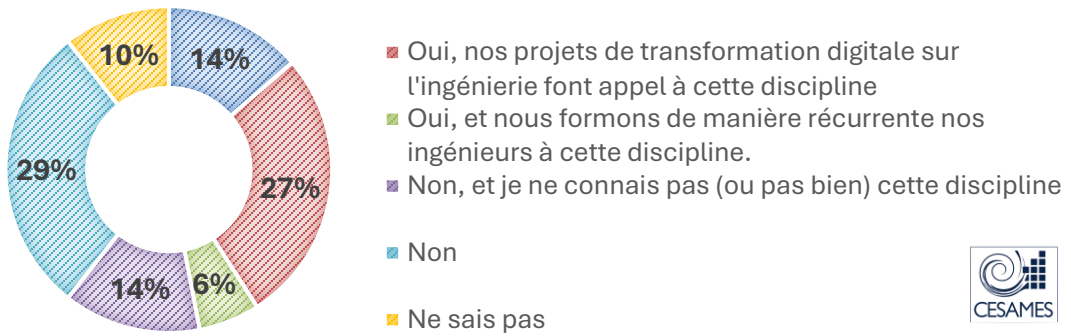


Illustration of an Enterprise Architecture framework

Enterprise architecture as a **consistency workspace**

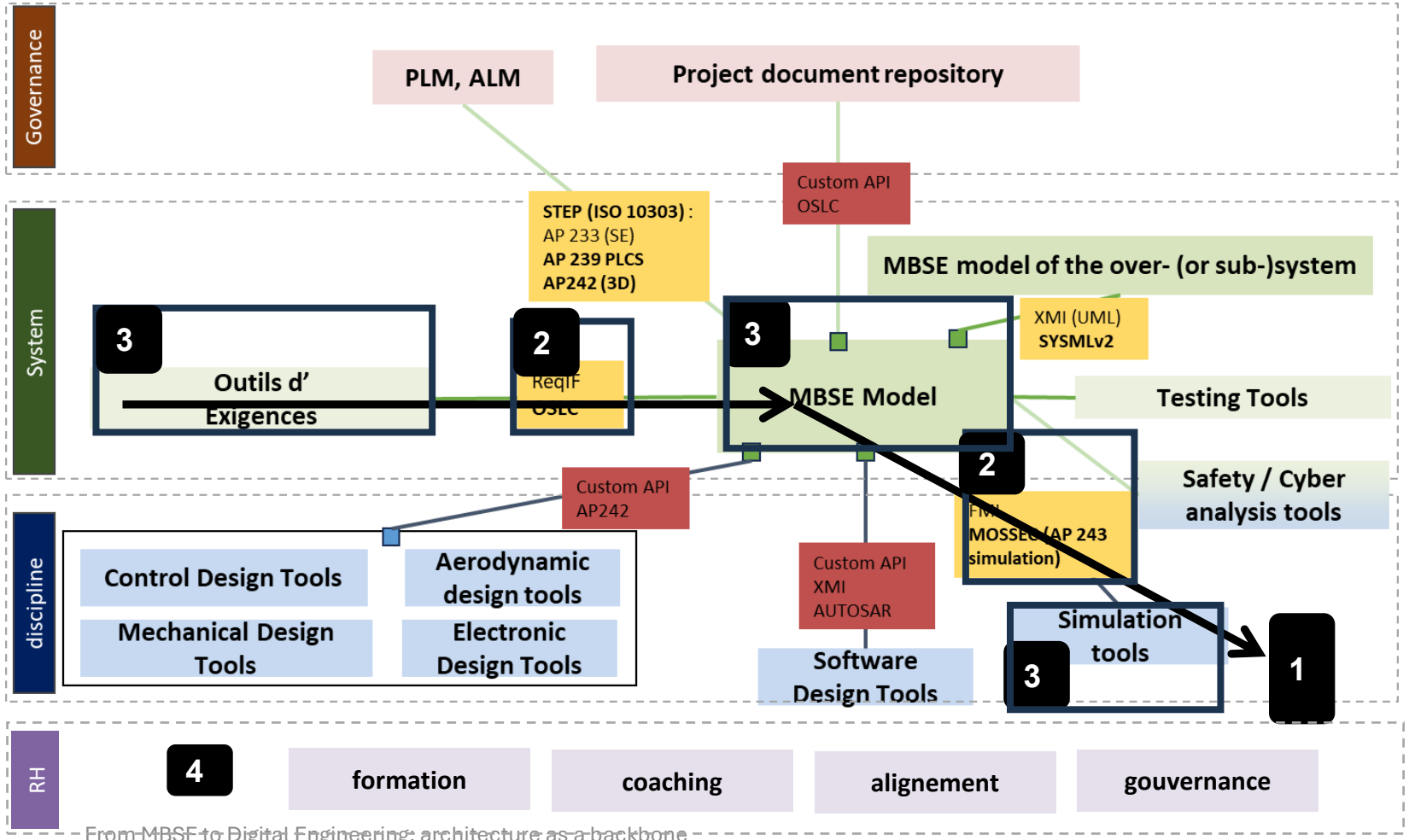
Seeking to unify **languages** or **ontologies** is **illusory**. Each area has its **own vision** of the system. Rather, the challenge is to create a **shared, sufficiently simple architectural framework** that allows these visions to coexist, **dialogue** and **collaborate**. These are practices that are **still limited within industrial companies**

To address the problem of the end-to-end toolchain, are enterprise architecture practices (system architecture applied to the design process) put in place? **(MBSE Observatory in France– CESAMES 2026 preliminary results)**



3.2 Towards architecture-centric digital engineering

The implementation of **Digital Engineering** is a transformation that must be **needs-oriented** before being **solution-oriented**: There is no point in **automating what doesn't work!**



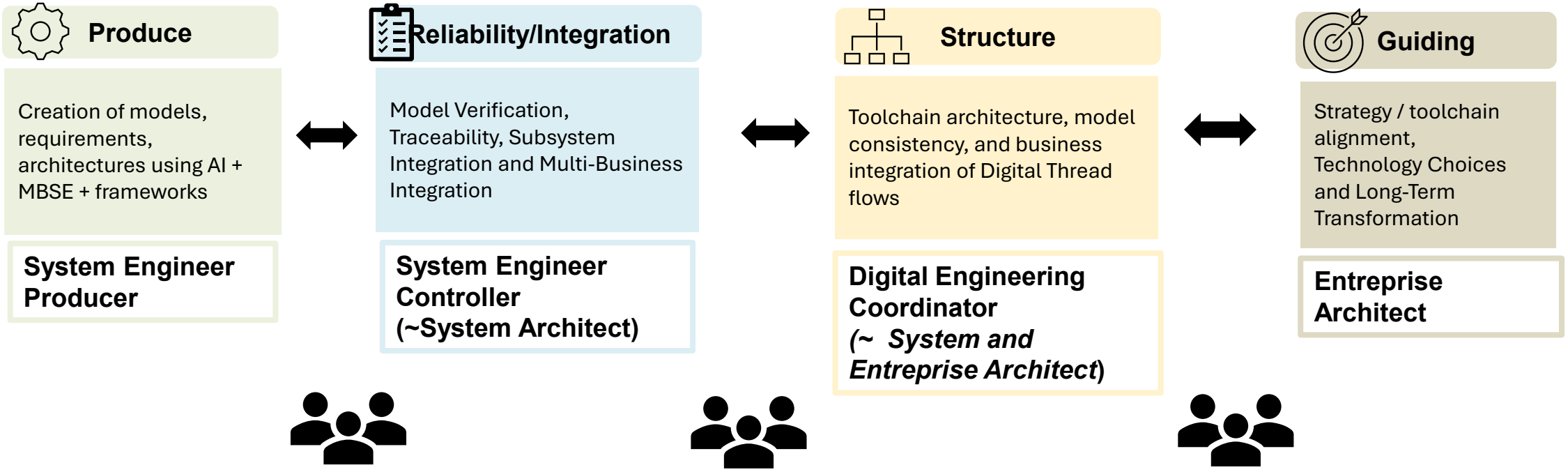
Implementation principles

1. Clarify **company-level needs** and identify **priority** digital threads
2. Choose **standards** and **tools adapted** to your industrial context and priority use cases
3. Structure your models in a **consistent** way and **simplify semantics** in a voluntary and shared way
4. Deploy **training** and create a **sustainable** internal **culture**

! The **risk**: being **tool-centric** and **standard-centric**

3.3 Onboard new architects

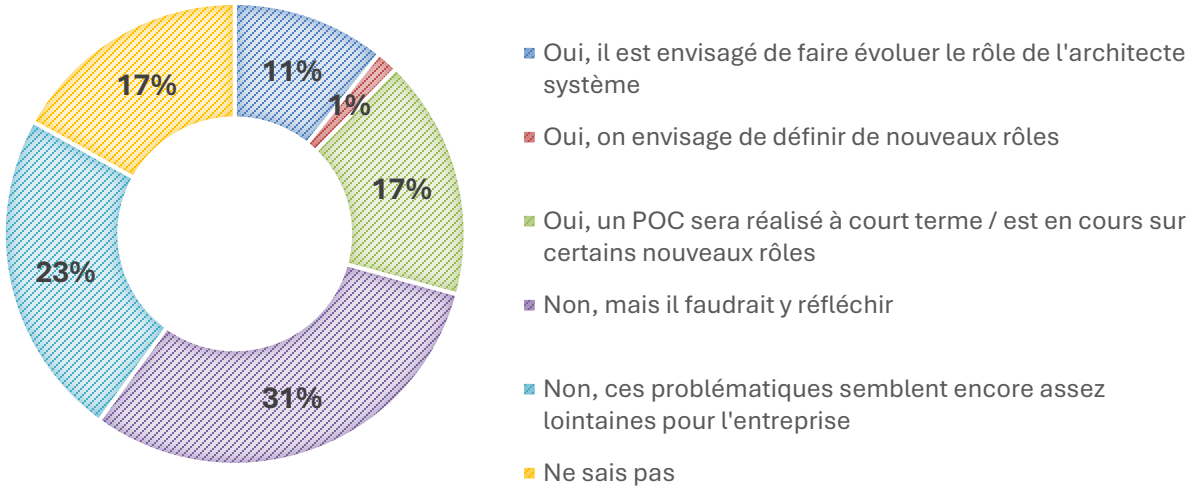
Digital engineering will simplify and **increase** the creation of **models**, also increasing the **amount of data** to be **processed** by an engineer: The challenge shifts towards their **consistency**, **integration** and **alignment** with the **strategy**, through **collaboration** between **several architectural** roles.



More architects' roles mean both more **expertise** but also more **collaboration**, **integration** and **human convergence**: we will have to **learn to talk to each other**!

From MBSE to Digital Engineering: architecture as a backbone

6.4 The role of the system architect and the various MBSE players will evolve with the industrialization of MBSE, its integration into a wider chain and the advent of AI. Are these reflections on the future role of the architect underway?
MBSE Observatory in France– CESAMES 2026 preliminary results



Thank you for your attention!

And you, how do you see the role of the architect evolving?