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Presentation #77

An integrative approach proposal for CK Theory, MBSE and Configuration Management

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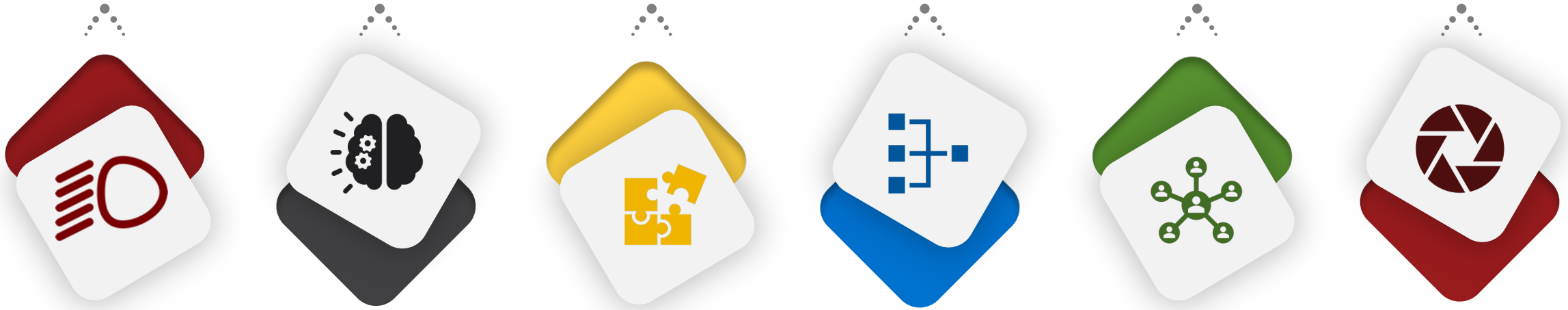
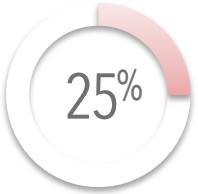
Agenda

1. Why we decided to put light on this topic
   - Starting point is an operational headlight issue
2. Product Modification seen as an “Innovation”
   - CK Theory as a way to tackle Innovation reasoning
3. What is missing
   - Limitations and shadow zones of the original C-K Theory
4. How to complement
   - System Engineering and MBSE are not just about Product / Service
5. The bridges
   - How to extend CK Theory taking into account Dev Process and Data
6. How to go Forward
   - Feedback and Q&A

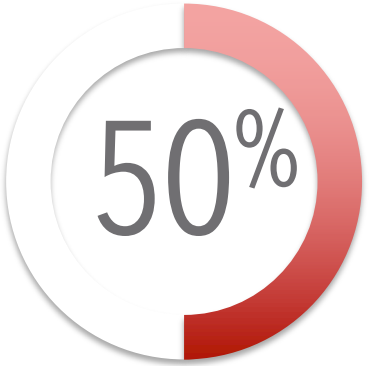


Why we decided to put light on this topic

Starting point is an operational headlight issue



While only one quarter of driving is done at night*



50% of traffic deaths happen **at night***

*Source : NSC - https://www.nsc.org/road-safety/safety-topics/night-driving

Modifying car features that could impact security items (like headlights) without conducting systemic study…

… is like driving by night, in a blizzard, without having… good headlights !

Why we decided to put light on this topic

Starting point is an operational headlight issue

Modification Study

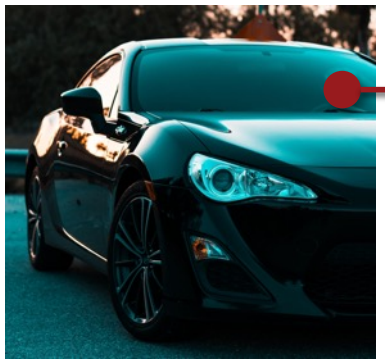
Root cause Analysis

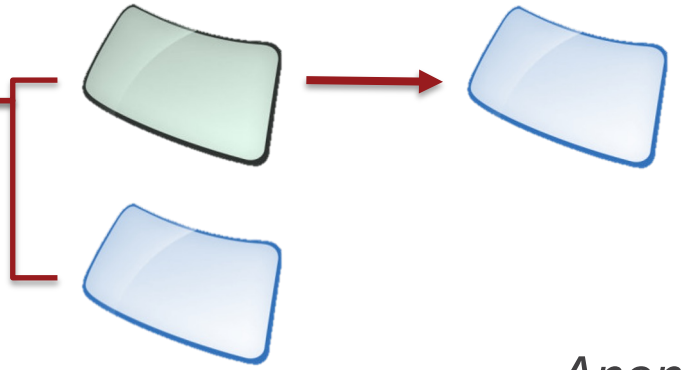
Year N — Year N+3 — Year N+4 — Year N+6 — Year N+7

For a car model, sales are launched with 2 Windshield Colors :
- **Green** Windshield
- **Blue** Windshield

Product and Procurement suggest a modification of the **Blue Windshield** version (cost and feature optimization)

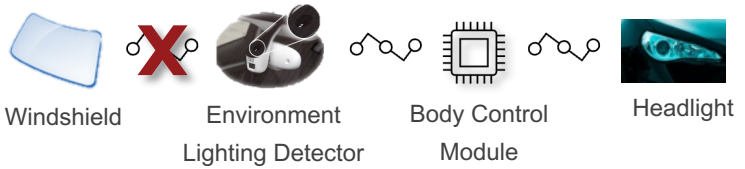
Customers' complaints showed **issues with Automatic Lighting System**





After study, **modification is implemented for new cars**

After months of study, the root cause is brought to light : **calibration of the Light Sensor**, which was… behind the Windshield



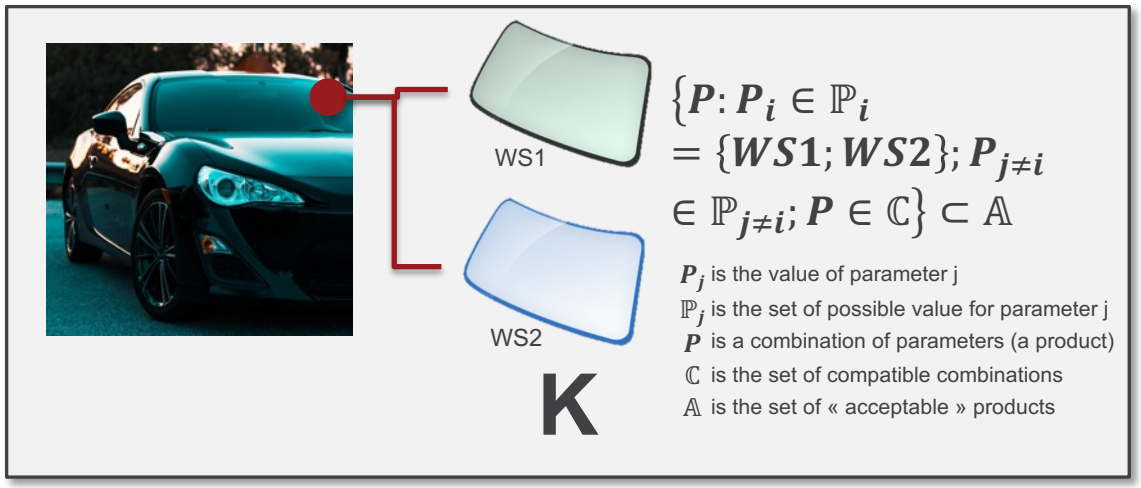
Anon. real use case

Product Modification seen as an “Innovation”

CK Theory as a way to tackle Innovation reasoning

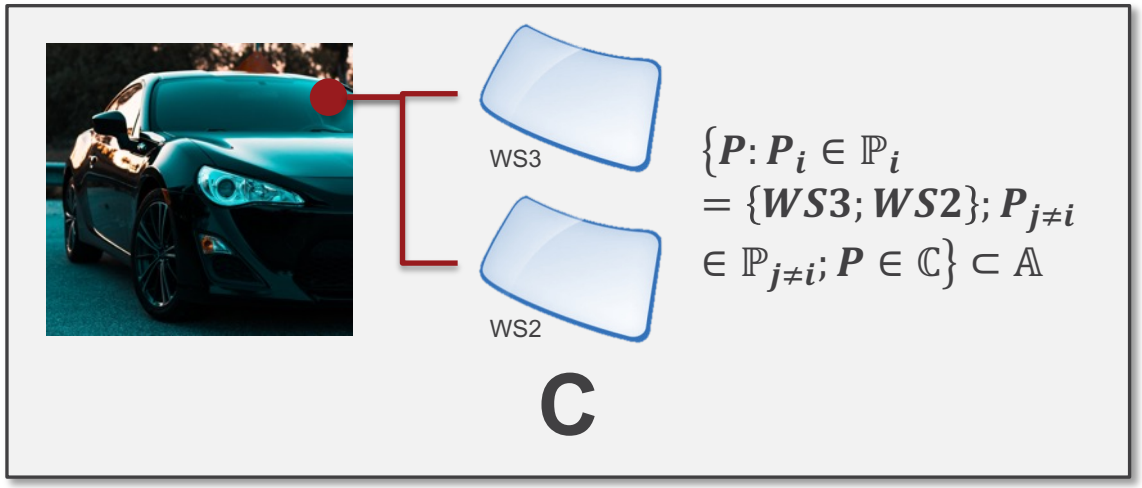
For this late-stage Product Modification, we propose to apply this formalism:

Product with its initial variants **is known** as “acceptable” (part of A subset, which is by definition the subset of “Acceptable” Products)



→ This proposition is part of **Knowledge space**

“Acceptability” of the new variant of Product is **not known (not decidable… yet)**, neither the impact on other parameters



→ This proposition is part of **Concept Space**

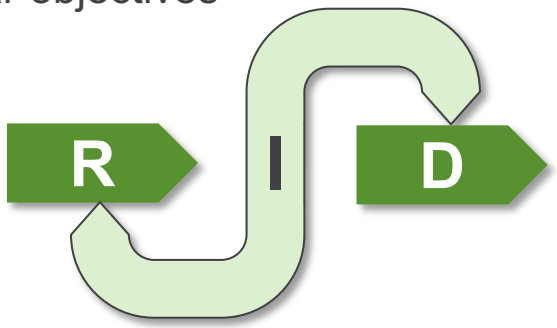
“Innovation” reasoning will be the **treatment of this Concept**, by **mobilizing existing knowledge**, **creating knowledge**, or **modifying Concept**

Product Modification seen as an “Innovation”

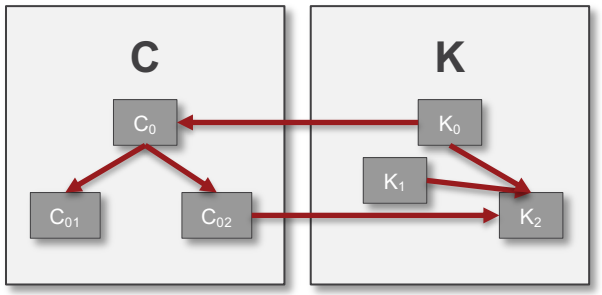
CK Theory as a way to tackle Innovation reasoning

CK Theory, introduced by Hatchuel and al. [1], is positioned in RID Model [4] (for **Research**, **Innovation** and **Development**) :

- **Research** is the controlled process of extending knowledge and competencies,
- **Innovation** is the co-evolution of Product and Competencies, in conjunction with Value definition
- **Development** is the controlled process of activating knowledge and competencies to specify an artefact with clear objectives



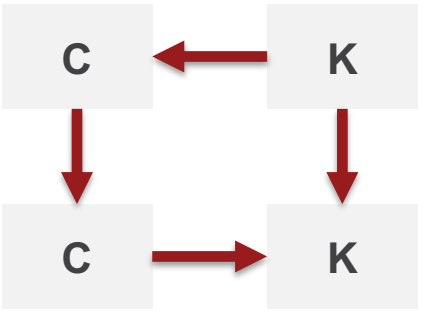
How then to organize I ? CK Theory’s formal framework describe the co-evolution of Product Concept and Knowledge to support it, where :



- **Space K** is the space of **Knowledge**. Knowledge is a proposal that has a logical status
- **Space C** is the space of **Concepts**. Concepts are undecidable propositions in K (neither true nor false in K) about some partially unknown objects

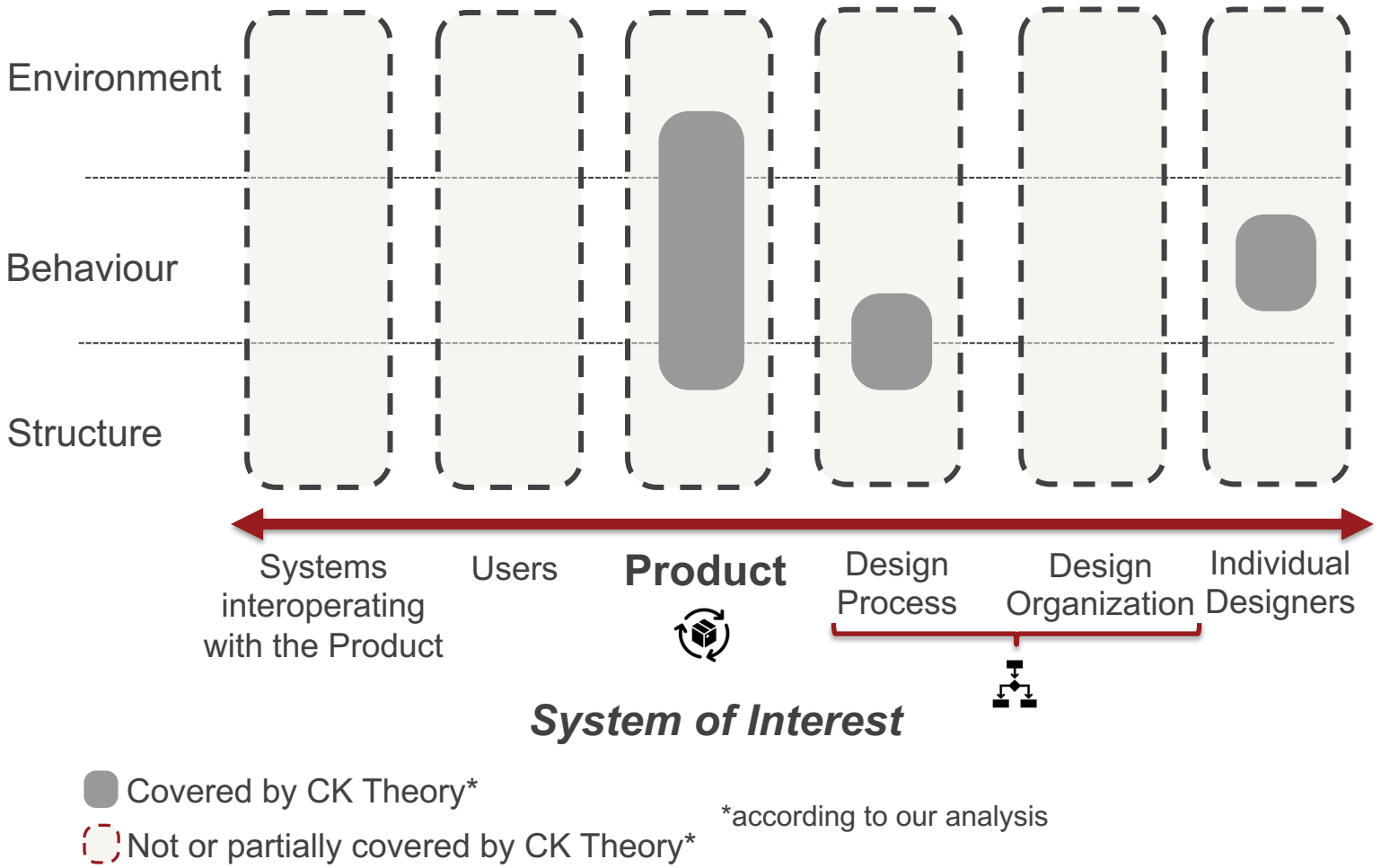
Innovation Reasoning is seen as a set of operators’ execution in both space :

- **Concept Expansion** (C→C and K→C) : it’s the addition / substraction of « properties » to the concept
- **Knowledge Expansion** (C→K and K→K) is the addition of knowledge



What is missing

Limitations and shadow zones of the original C-K Theory



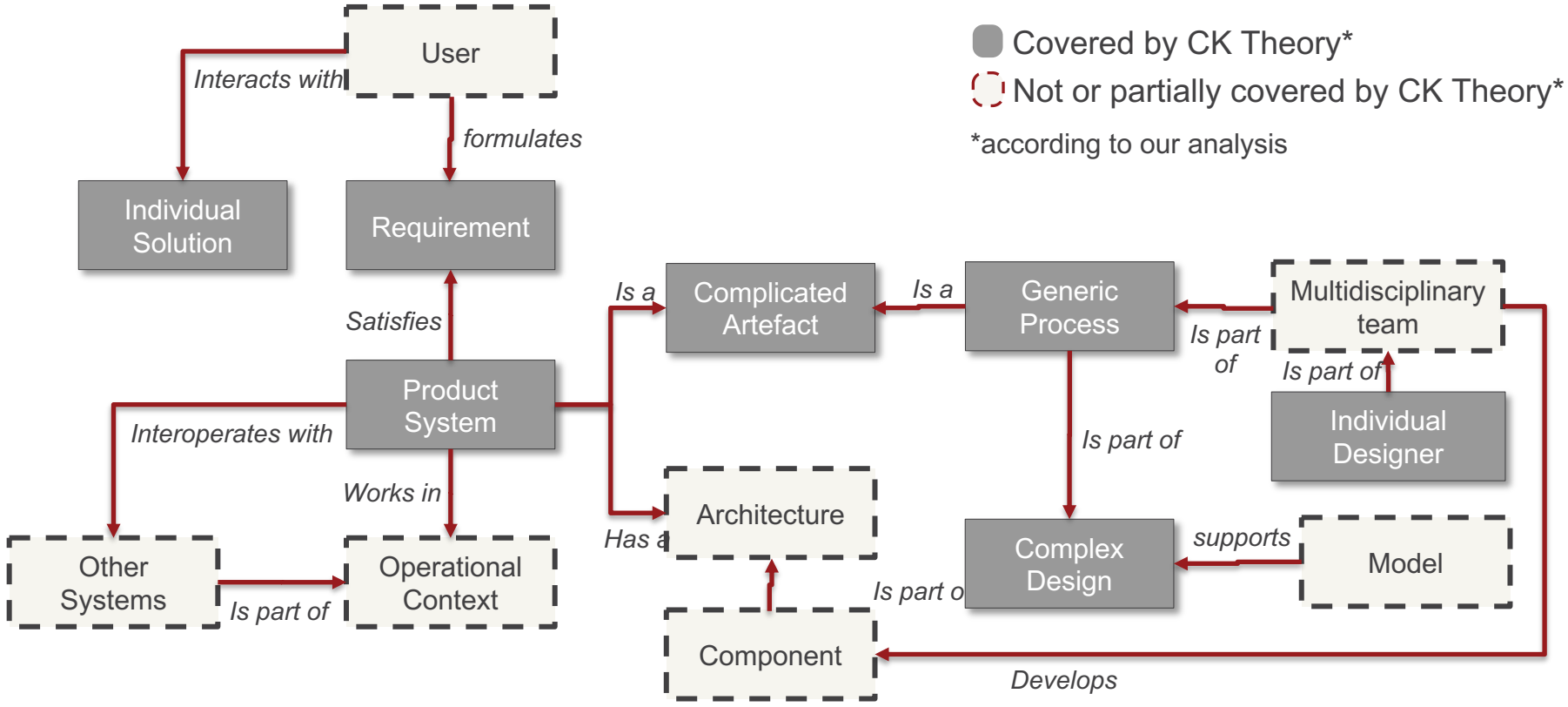
CK Theory is not meant to address exhaustively the overall design process, but to introduce **a powerful theoretical framework to design, implement and qualify a design heuristic**

Nevertheless, some limitations have been raised (mainly by Coatena & al. [4]):

- **No found taxonomy to define a concept** (Requirements ? Functions ? Behaviour ? Product Structure ?)
- **Restrictive Definition of knowledge** (vs. the usual Data – Information – Knowledge gradient)
- **Partial integration of environment** and situatedness of the designer (cf. extension to C/K/E by Kazacki & al. [3])
- **Partial integration of the collective dimension** of the design process (cf. also [2])

How to complement

System Engineering and MBSE are not just about Product/Service



Adapted from Ontology detailed by Bonjour & al. [5] (translated from French)

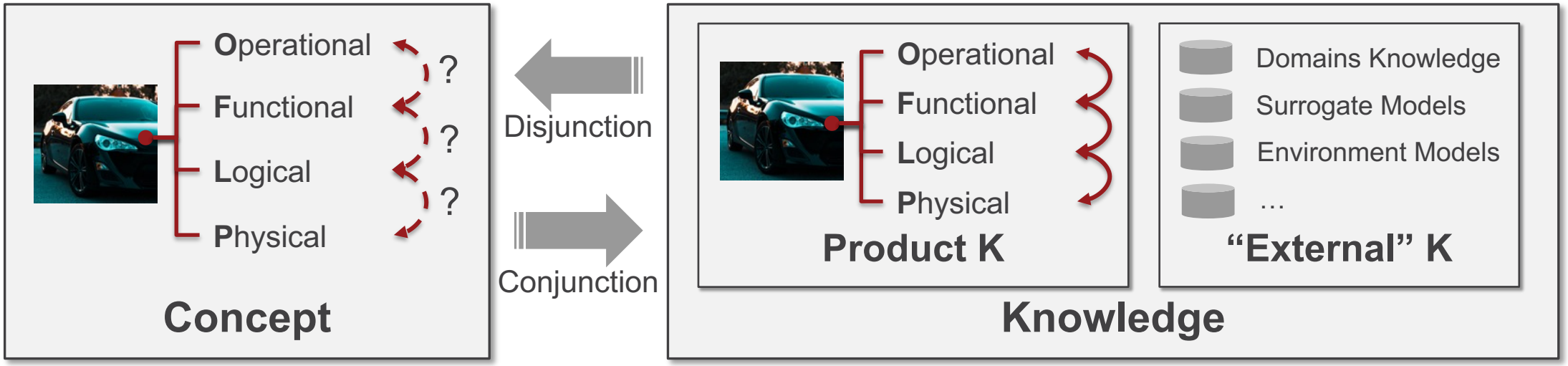
System Engineering focus on **Product,** in terms of **structure, behavior and environment**

It also aims to describe **Design Process and Organization**, as **systems interacting with Product**

The bridges

How to extend CK Theory taking into account Dev Process and Data ?

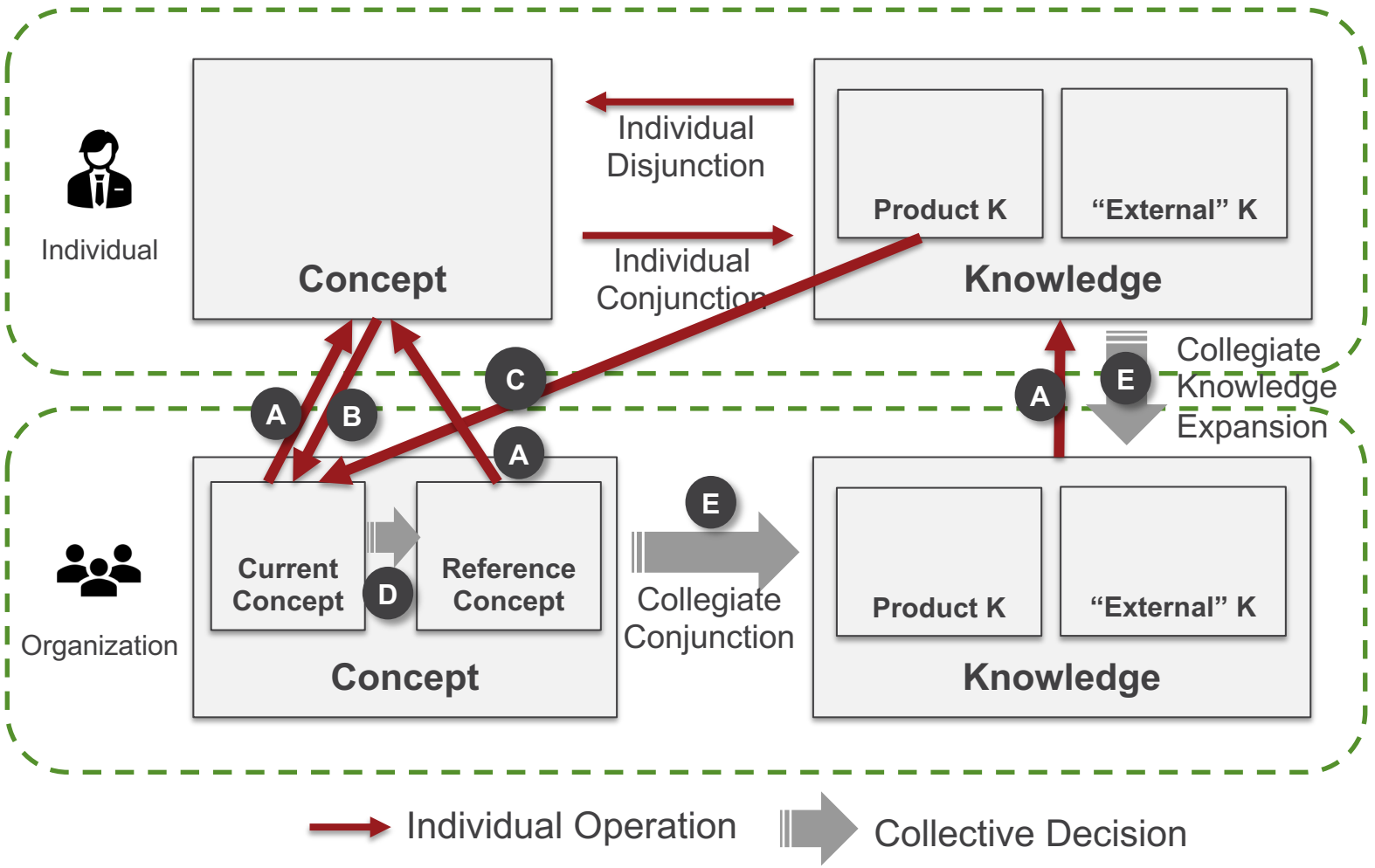
To complement CK theory, and leverage its powerful approach, we propose to blend it with MBSE Concepts, as proposed by Li & al. [6] and Jin & al. [7]



- **The Product**, both in Concept Space and Knowledge Space, is modelled an **usual MBSE Metamodel**
- A Concept is a **Product Variant** where **consistency in MBSE terms is not validated** (undecidable)
- **Development process** is then seen as
  - **Discovery of new concept** (K→C : Disjunction, C→C : Partition / Inclusion)
  - **Extension of Knowledge** (K→K)
  - **Validation of a Concept**, turning it into Knowledge in CK terms (C→K: Conjunction)

The bridges

How to extend CK Theory taking into account Dev Process and Data ?



To take into account the collectiveness of the Development Process, we propose following adaptations of the framework:

- We introduce collective C and K spaces, to describe synchronicity / asynchronicity of the process, information and knowledge sharing
- We distinguish 2 states for a concept in Collective Concept Space, to ensure reliability of data sharing
- Individual has access to all collective Concept and Knowledge **(A)** that can be either pushed or pulled
- Individual Concept **(B)** and even Individual Product Knowledge **(C)** can be individually integrated in collective **Current Concept Space,** but not in Reference Concept Space
- Decision to promote concept as referent is collective **(D)**, and so is Decision to expand Collective Knowledge **(E)**

How to go forward

Our objectives: refine this proposal, perform fit & gap analysis with current processes, capabilities and solutions, confirm impacts and benefits

We want to evaluate both its **descriptive an prescriptive contribution**

For this, we need your feedback

Appendix

How to reach Research Team

Omar ABDERRAZIK

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Main Resources

- [1] Le Masson, Pascal & Hatchuel, Armand & Weil, Benoit. (2020). **C-K Design Theory.** Integrated Design Engineering-Interdisciplinary and holistic product development,
- [2] Hatchuel, Armand & Le Masson, Pascal & Weil, Benoit. (2009). **Design theory and collective creativity: A theoretical framework to evaluate KCP process.** DS 58-6: Proceedings of ICED 09, the 17th International Conference on Engineering Design. 6. 277-288.
- [3] Kazakci, Akin & Tsoukiàs, Alexis. (2004). **Extending the C–K design theory: A theoretical background for personal design assistants.** Journal of Engineering Design. 16
- [4] Coateana, Eric & Forest, Joelle & Choulier, Denis. (2010) **The Engineering Design CK Theory: Contributionsand Limits.** 22nd International Conference on Design Theory and Methodology, Montréal,Canada. pp.83-92
- [5] Bonjour, Eric & Deniaud, Samuel & Micaëlli, Jean-Pierre. (2009). **Conception complexe et ingénierie système.**HERMES Science. Les systèmes techniques. Lois d'évolution et méthodologies de conception.,Lavoisier, 83-101
- [6] Li, Xinyu & Chen, Chun-Hsien & Zheng, Pai & Wang, Zuoxu & Jiang, Zuhua & Jiang, Zhixing. (2020). **A Knowledge Graph-Aided Concept–Knowledge Approach for Evolutionary Smart Product–Service System Development.** Journal of Mechanical Design.
- [7] Jin, Yili & Jinzhi, Lu & Wang, Guoxin & Wang, Ru & Dimitris, Kiritsis. (2021). **Semantic Modeling Supports the Integration of Concept-Decision-Knowledge.**

Thank you

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