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# Modeling and experimentation of co-design methods to develop new services by leveraging a Digital Twin of the Earth

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# Modeling and experimentation of co-design methods to develop new services by leveraging a Digital Twin of the Earth

PhD thesis by Malik Terfous (malik.terfous@minesparis.psl.eu) supervised by Pascal Le Masson, Benoit Weil and Alexandre Azoulay



Context and empirical motivations

## Contemporary grand-challenges

Modern society faces numerous grand challenges that demand innovative solutions. Climate change, biodiversity loss, resource depletion, and global health crises require international cooperation, advanced research, and adaptive policies. Addressing these issues ensures sustainability, environmental protection, and resilience.



## A strong hypothesis related to « Open-data »

Earth observation data policies assumed that open access would drive high-value applications. This led to strong global initiatives such as: GEO (2005), free Landsat data (2008), and Copernicus (2014). While meteorology benefited from it, other sectors, like sustainability, saw limited impact.



### The European Space Agency

Entrusted entity engaged by the European Union on the Destination Earth project :  
 • Responsible for the development of the Destination Earth core service platform



### Mines Paris PSL

Involved in the co-design Work Package of the E-Shape projects from 2019 to 2021 :  
 • Double specialization : earth observation & management of design and innovation activities



### The city of Marseille (France)

The city of Marseille is has the typical profil of a potential end-user of DestinE :  
 • Faced with critical issues related to climate change & selected by the European Union for the program Climate Neural & Smart Cities



Contract

Partnership agreement

### « GRAND-DISTANCE »

No established relationship, very different ways of working, expertises and objectives

### Our collective goals :

To develop Co-Design Methods & Toolkit for DestinE to put the users at the center of service development  
 To develop a supersite to help the city of Marseille to reach its objectives toward sustainability

Methodology

## Destination Earth: an overview

Destination Earth (DestinE) is an ambitious EU initiative to create a highly accurate digital twin of Earth. Using cutting-edge data science, high-performance computing, and Earth system modeling, its objectives are to provide insights into environmental changes, support sustainability, and strengthen societal resilience.



## Co-designing with stakeholders

Our active involvement within this project allowed us to deploy an intervention research strategy to support our data collection and analysis. As our main prerogative in this project is to structure the co-design activities between the platform owner and the focal users, we maintained close interactions (meetings, workshops) with these stakeholders on a weekly basis.

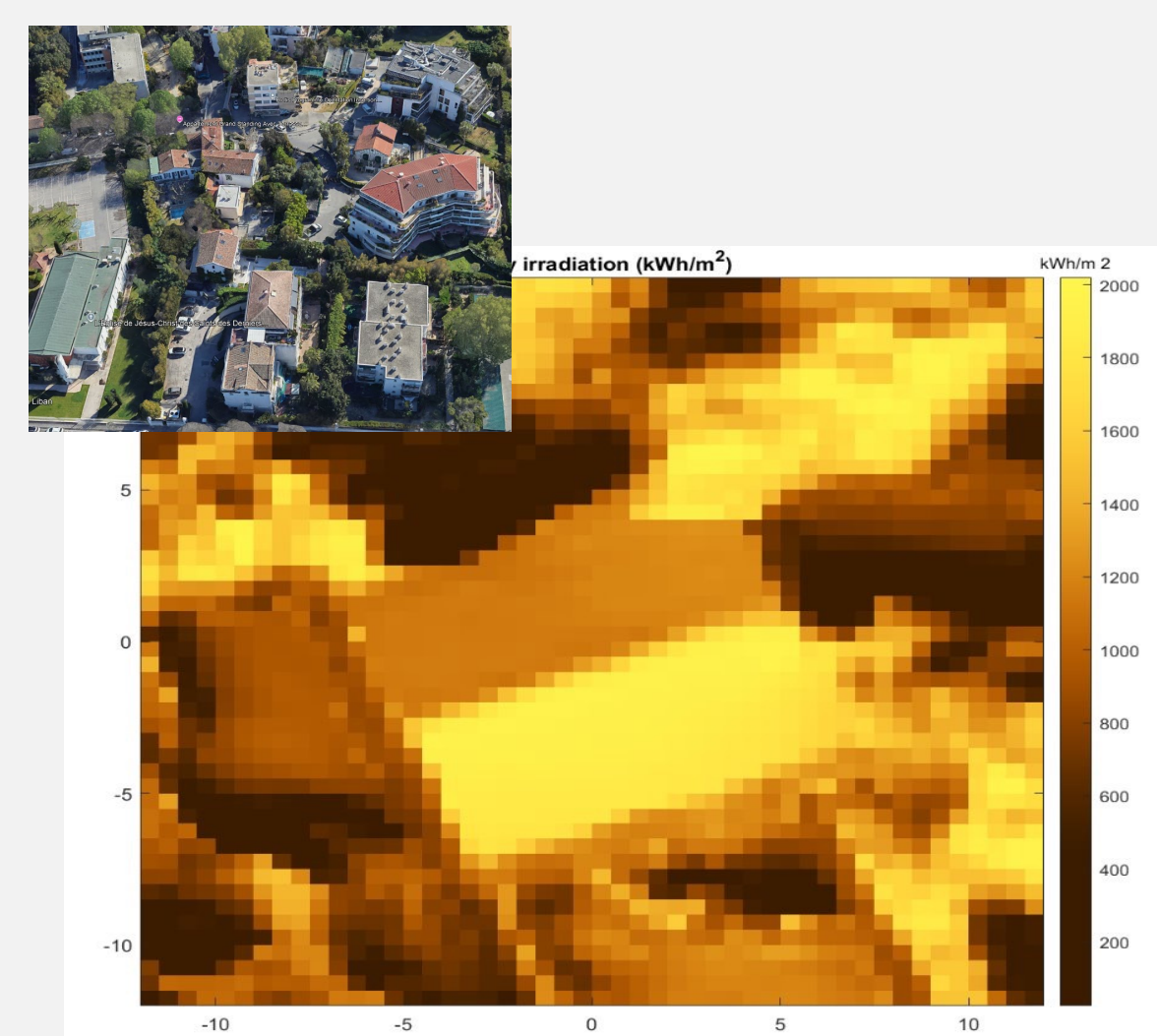


## I. Towards co-design-based platforms: Reconciling contextualization and the design of genericity through retrofit

A. Azoulay, M. Terfous, P. Le Masson, B. Weil

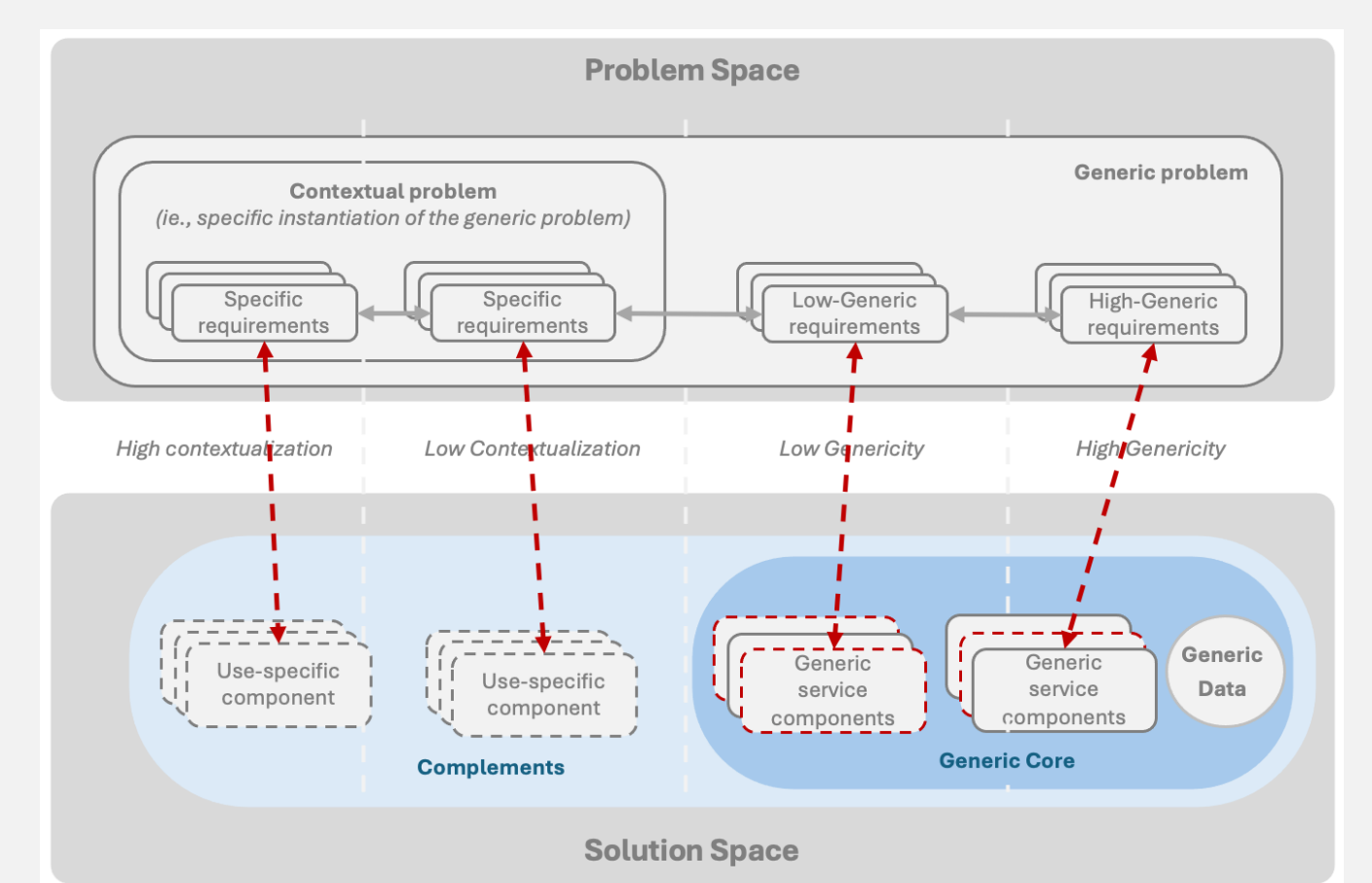
### Feeding the genericity

This mechanism expands the platform by integrating new generic resources across infrastructure, data, and services. First, linking complementary open datasets, like aerial lidar data, enhances its core capabilities. Second, ensuring compatibility with other platforms broadens generic solutions. Third, integrating standalone services, including open-source scientific models, reinforces functionality. Identified through workshops with users, these mechanisms support technical and cognitive retrofits, enabling adaptability to other contexts.



### Architecturing for retrofit

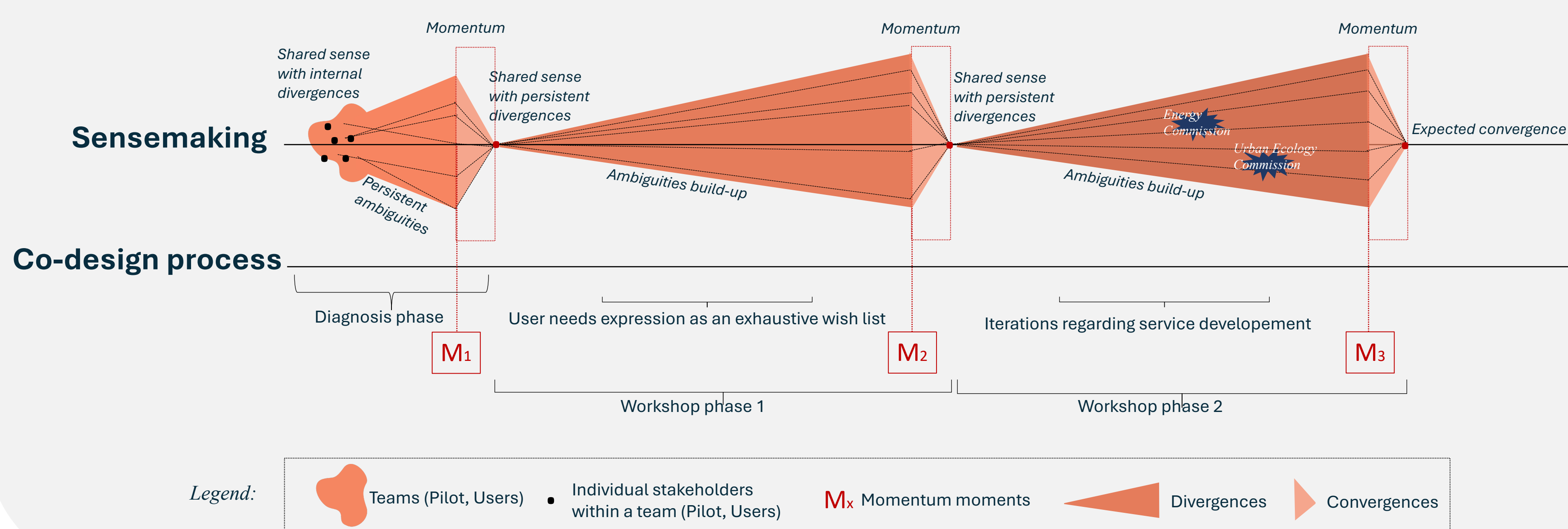
This mechanism focuses on designing services with a layered modular logic, separating generic and context-specific components. Contextual layers define geographical scope, such as DSM for soil characterization, while generic layers integrate platform data and scientific models for computations. This structure helps match generic problems with reusable solutions and context-specific problems with tailored responses, supporting services integration. Architecturing for retrofit on context expansion and feeding genericity to enhance reusability.



Results

## II. Make it make sense: the transformative potential of co-design

M. Terfous, A. Azoulay, P. Le Masson, B. Weil



This result highlights co-design's dual role in fostering innovation and reshaping stakeholder relationships. By integrating sensemaking theory with the Concept-Knowledge (C-K) framework, it identifies key dynamics—divergence, momentum, and convergence—that drive the process. These dynamics help resolve cognitive, organizational, and technical ambiguities, building a resilient collective design capability. However, transformation is not automatic; deliberate orchestration of sensemaking transitions is essential to avoid stagnation and misalignment. Co-design is not merely a methodological tool—it is a dynamic space for redefining roles, expertise, and purpose. By structuring external events to design progressive sensemaking, co-design enables stakeholders to collaboratively explore the unknown and transform ambiguities into actionable pathways.

