MELISSA
MICRO-ECOLOGICAL LIFE SUPPORT SYSTEM ALTERNATIVE

2022 MELISSA CONFERENCE
8-9-10 NOVEMBER 2022

CREATING A CIRCULAR FUTURE

Circularity indicators and digitalisation for monitoring circular space and terrestrial systems

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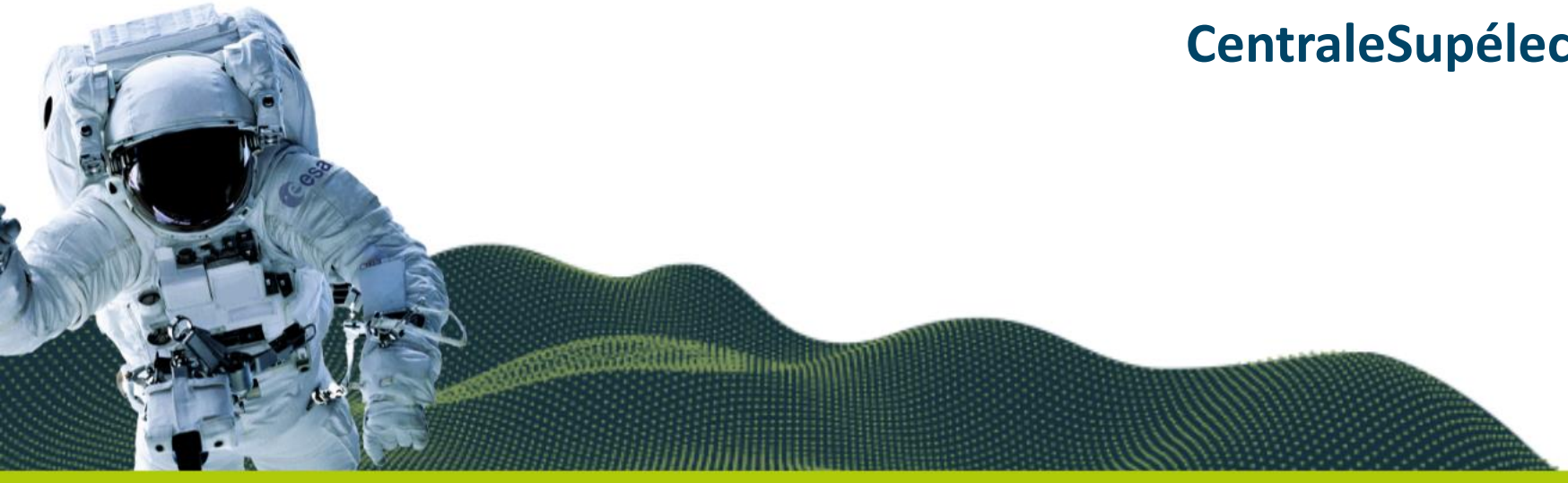


CentraleSupélec

Agenda

1. Terrestrial vs. space systems in a Circular Economy perspective

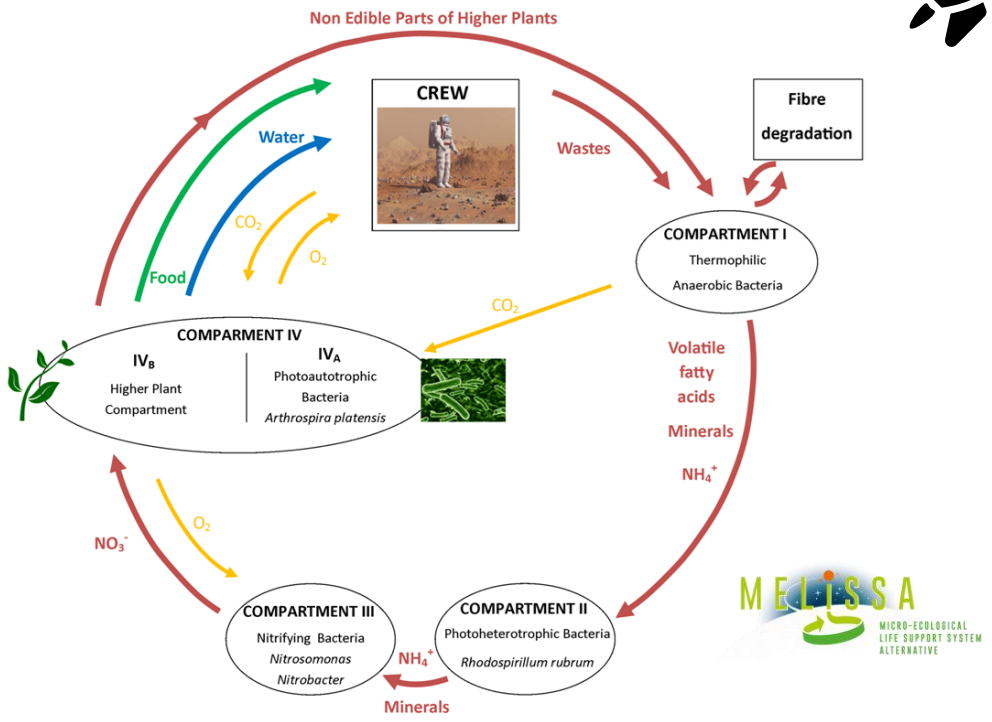
2. Designing and monitoring more circular systems
   - Circularity indicators
   - Digitalisation

3. Towards a simulation platform for circularity performances

4. Perspectives to bridge the gap between Systems Engineering and Circular Economy

Terrestrial vs. space systems in a Circular Economy perspective

Example of space system to circularize



Example of Earth system to circularize

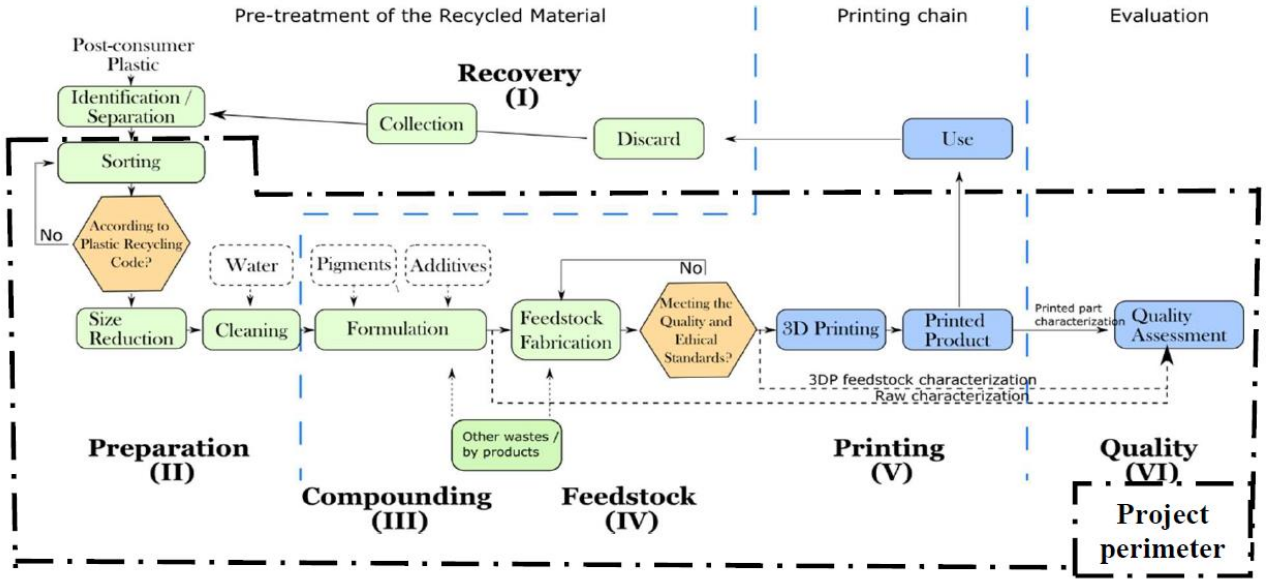


Figure 1: Recycled thermoplastics chain proposed [21].

Terrestrial vs. space systems in a Circular Economy perspective

Circular space system

- Maximizing the efficiency of M- and E-loops to:
  - allow long term space travels
  - keep the crew alive and in good health
- Impacts (like pollution) on the ‘external world’ (space, the Moon or Mars surface!) are ‘not’ an issue
- Economic issues are predominant during the design of space systems but are not a criterion to consider during the missions themselves.

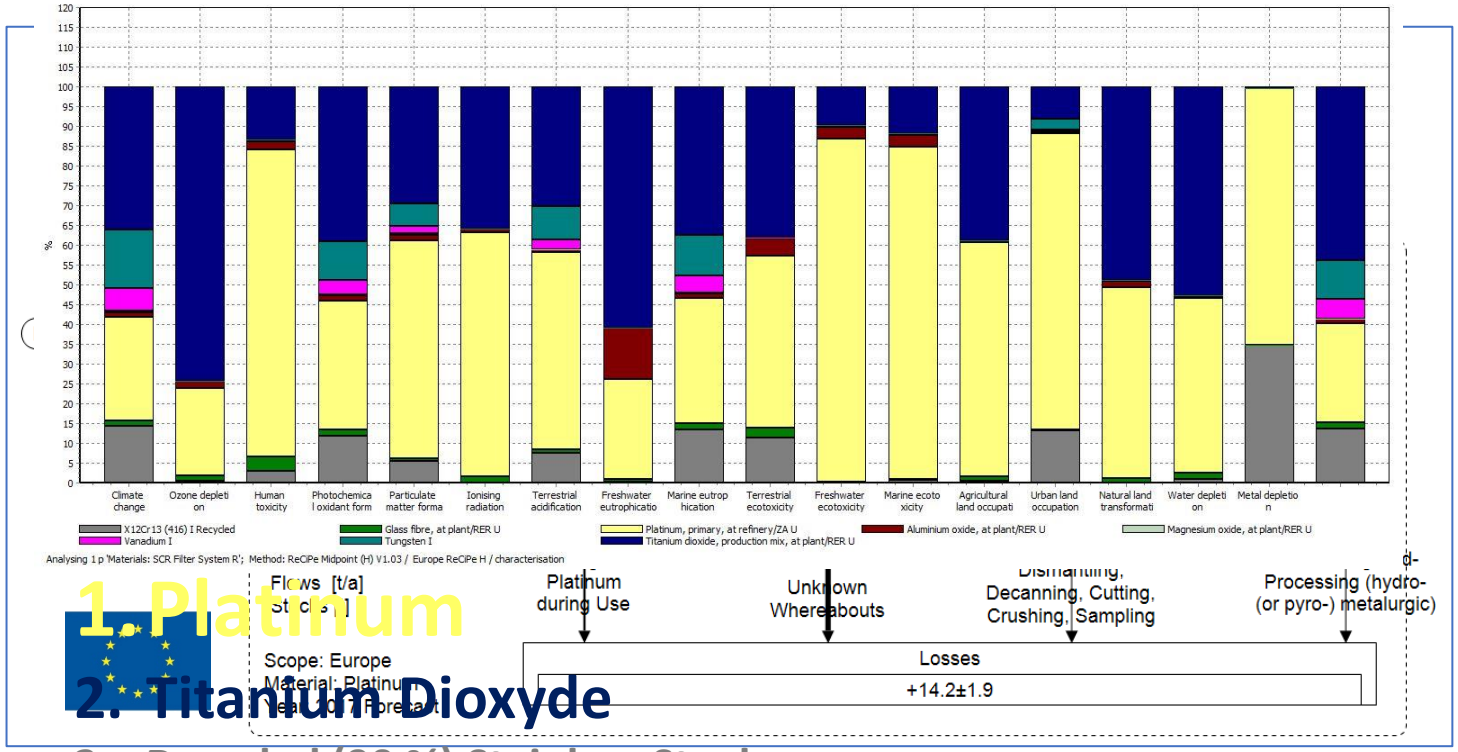
Circular Earth system

- Maximizing the efficiency of M- and E-loops to:
  - minimize the use or resources and the environmental impact
  - while maximizing the economic performance on the entire life cycle.
- Environmental impact = as much important as the economic performance… depending also on sustainability paradigm – weak or strong – chosen
- + social dimension!

Designing and monitoring more circular systems

Historical engineering tools

- ***Material Flow Analysis (MFA)*** is a systematic assessment of the flows and stocks of materials within a system defined in space and time [MFA Handbook 2004]
- ***Life Cycle Assessment (LCA)*** is a compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle [ISO 14040:2006]



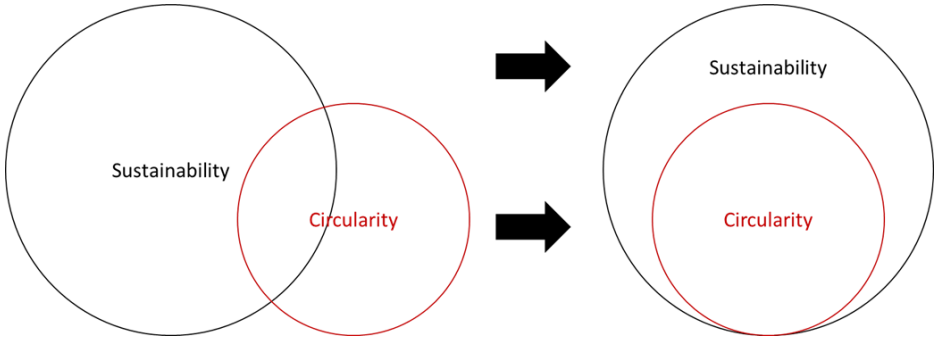
1. Platinum
2. Titanium Dioxyde
3. Recycled (90 %) Stainless Steel
4. {Tungsten, Vanadium}

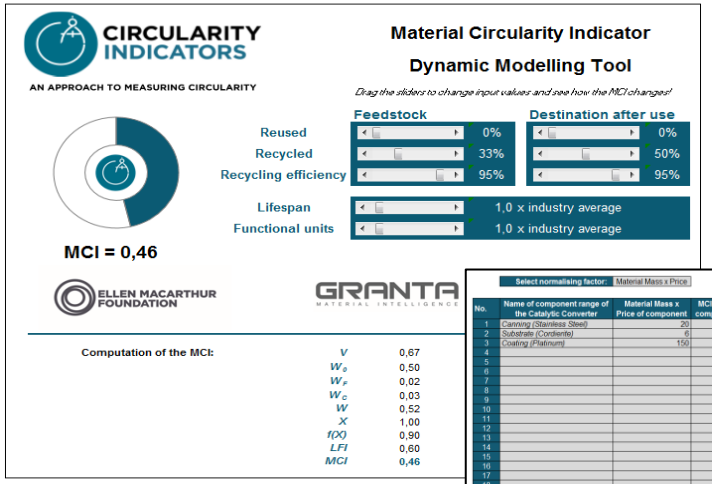
Designing and monitoring more circular systems

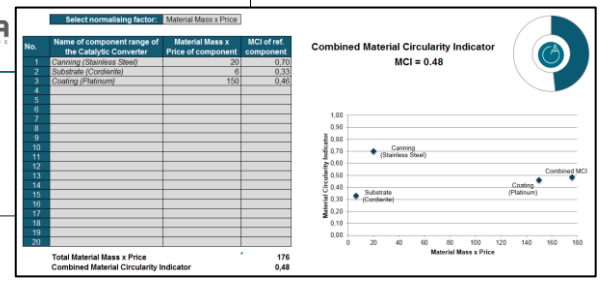
Circularity Indicators (C-Indicators)

- Increasing development since 2010s
- C-performance = resource use, resource loss, renewability, etc.

- *"However, due to the intrinsic focus of CE on value and material preservation, **most of the proposed methods focus on measuring material consumption**, with recycling being the most dominant CE strategy considered. Additionally, **the challenge lies in measuring the social dimension**, which remains largely uncovered by the proposed indicators and methodologies."* [Kravchenko et al. 2020]







[Ellen McArthur Foundation 2015]

Designing and monitoring more circular systems

Circularity Indicators (C-Indicators)

Different Levels of CE Measurement:

- Real vs. Potential Circularity
- Consequential vs. Intrinsic Circularity
- Units (kg; $; J; …) Issue - Single vs. Multiple Indicators
- Usages (Assessment, Improvement, Managerial, Benchmarking, Communication)
- + Distinction of Circularity Loops, etc.

Levels	Definitions	Examples
Macro	City, province, region, nation, society	19% of the UK economy is circular in 2010
Meso	Inter-entreprise Industrial symbiosis	Indicators used to assess the EIPs performance
Micro	Single company Products Materials	Input-Output Analysis in the manufacturing process

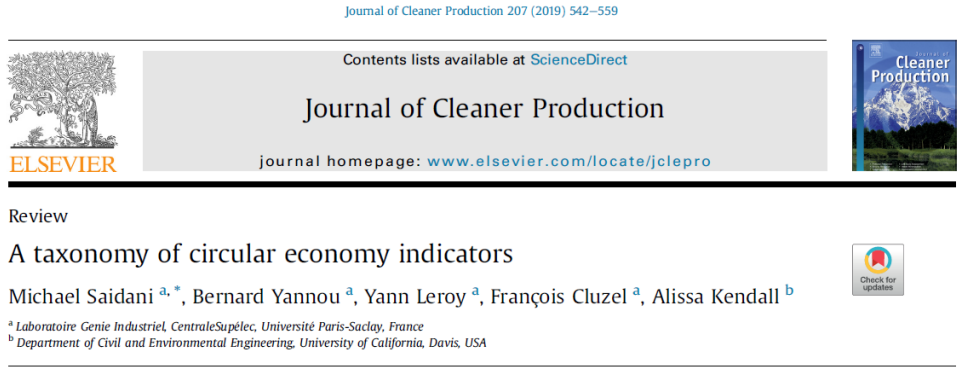
Designing and monitoring more circular systems

Circularity Indicators (C-Indicators)

to monitor and improve the circularity of a product, company, industrial value chain, territory…

Online platform to select C-indicators:

http://circulareconomyindicators.com/


Journal of Cleaner Production 207 (2019) 542–559

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Review

A taxonomy of circular economy indicators

Michael Saidani [a, *], Bernard Yannou [a], Yann Leroy [a], François Cluzel [a], Alissa Kendall [b]

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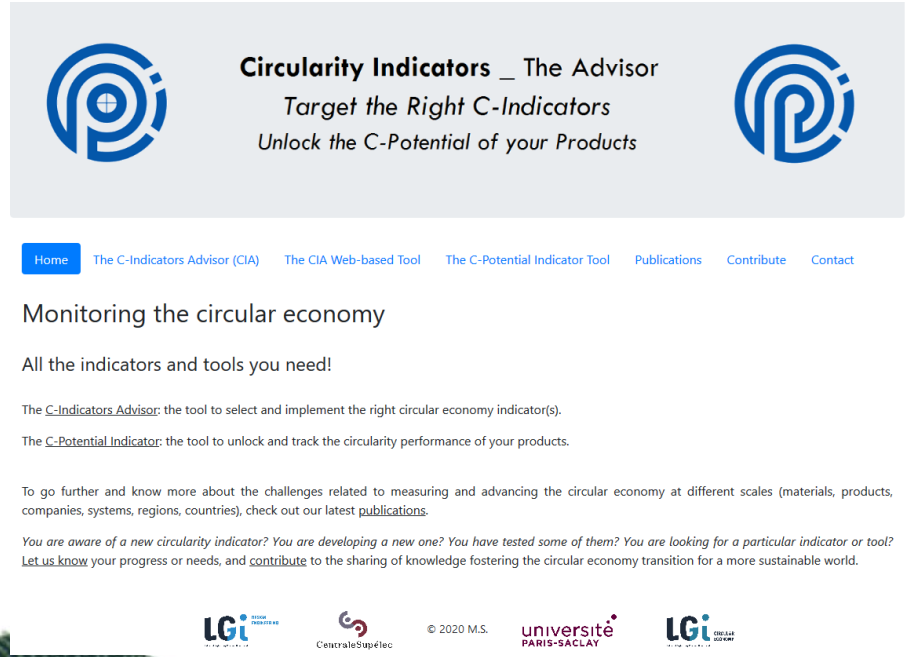
[b] Department of Civil and Environmental Engineering, University of California, Davis, USA



Designing and monitoring more circular systems

Digitalisation for Circular Economy

Nexus of circular economy and sustainable business performance in the era of digitalization

Rohit Agrawal, Vishal Ashok Wankhede, Anil Kumar, Arvind Upadhyay, Jose Arturo Garza-Reyes

International Journal of Productivity and Performance Management
ISSN: 1741-0401
Article publication date: 1 April 2021 Reprints & Permissions
Issue publication date: 15 February 2022

DOWNLOADS

WORLD ECONOMIC FORUM

CIRCULAR ECONOMY

How digitalization can help build a circular economy ecosystem

Aug 25, 2022

ELSEVIER
Procedia CIRP
Volume 64, 2017, Pages 19-24

The Emergent Role of Digital Technologies in the Circular Economy: A Review ☆

Aris Pagoropoulos, Daniela C.A. Pigosso, Tim C. McAloone

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https://doi.org/10.1016/j.procir.2017.02.047

One Earth
CellPress
Volume 4, Issue 6, 18 June 2021, Pages 783-785

Commentary

Toward a circular economy: The role of digitalization

Annika Hedberg [1], Stefan Šipka [1]

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https://doi.org/10.1016/j.oneear.2021.05.020

Although not actively recognized, the ongoing digital transformation can serve as an enabler and even as a catalyst for creating a circular economy. It is time to build on this potential and create a digital circular economy that can benefit people, businesses, and the planet.

Designing and monitoring more circular systems

Digitalisation for Circular Economy

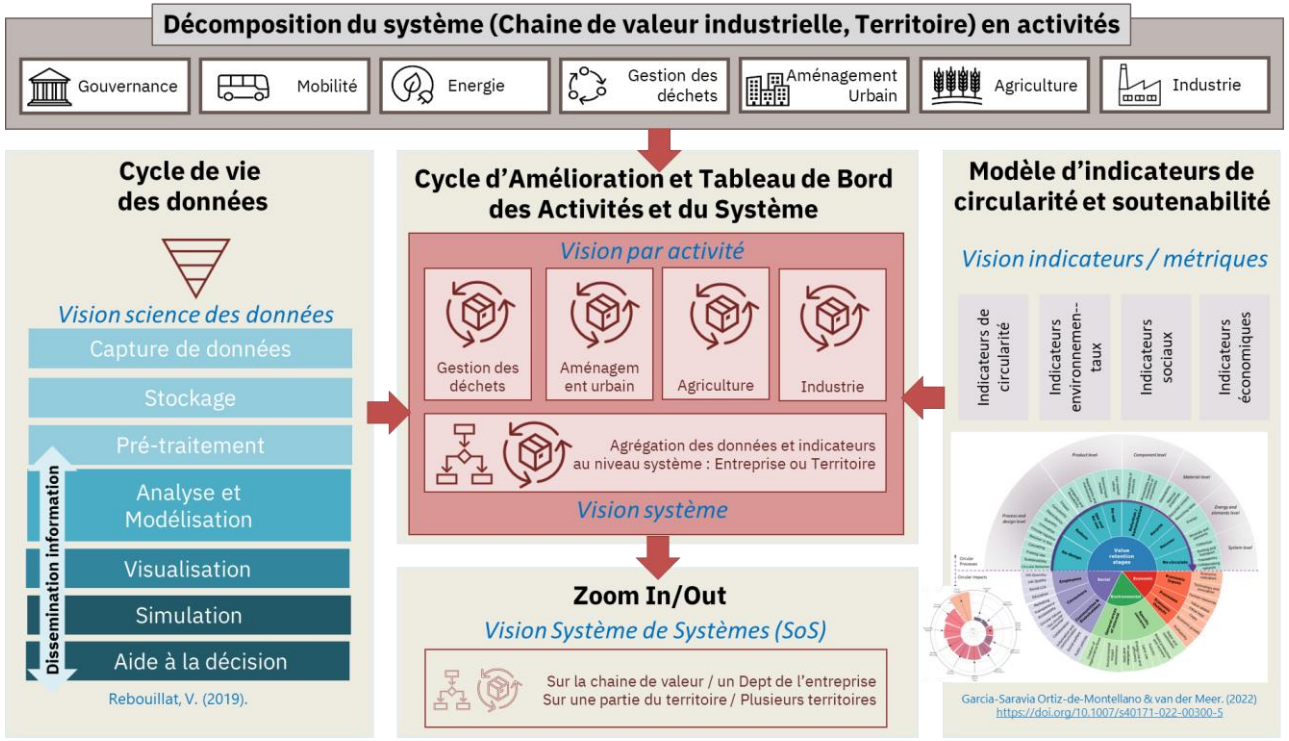
- Current tendency: digitalisation of territories and value chains

- Examples: in France, Program for the Digital Transformation of Territories in June 2021: « *a smart territory in which services and public policies are monitored by data, thanks to diverse digital tools* »

Towards a simulation platform for circularity performances

Launching of the CircularIT Alliance

- Quantify, improve and monitor the circularity and sustainability performance of industrial systems and territories
- **Objective:** develop a methodology from the diagnosis of key activities of an industrial company or a territory to the deployment of a digital platform to monitor and improve circularity and sustainability



Towards a simulation platform for circularity performances

Scenarios Definition

HCI

Users

esa

ThalesAlenia Space

Goals

- system architects
- technological designers

impacts

Inputs

– Environment
– **Mission assumptions**
– Crew induced metabolic loads
– Crew time allocation
– System power requirements
– Logistics hypothesis

impacts

DECISION SYSTEM : ALiSSE Global evaluation Level (**OSCAR's** Brain Level)

*Run a **mission scenario,** System decomposition into **requirements** ,System **evaluation** and **comparison***

VARSITY ALiSSE

Coordination, Configuration

Metrics

INFORMATION SYSTEM : ALiSSE Resource level (**OSCAR's** Brain Level)

Energy, Matter & Flow Management

ALiSSE

Dealing with request and configurations

Reference model

- **Interactions** & **Flow** management
- **Thermal** and **electrical** energy management
- Resources Calculation

Control of the global loop

Currently not existing for the global dynamic loop

Metrics calculation

Control variable calculation

Models **calibration**

control

connection

Presentation at 10:30, session System Studies 2/3

OPERATION SYSTEM Technological level – based on **OSCAR** 6 layers - *Physical, Chemical, Thermal, Process modelling* :

Chemical & Process models

STATIC Matlab Simulink models with manual links

Metabolic flow calculation tool

STATIC **process simulators tool** (ASPEN, Gprom, ProSim)

Kinetic transfer aspect ENGINSOFT

what is limiting & what is the main actor :

DYNAMIC Matlab Simulink **material balance models**

DYNAMIC CFD models

Potential incompatibility in a common platform / different interests

Physical & Thermal Model

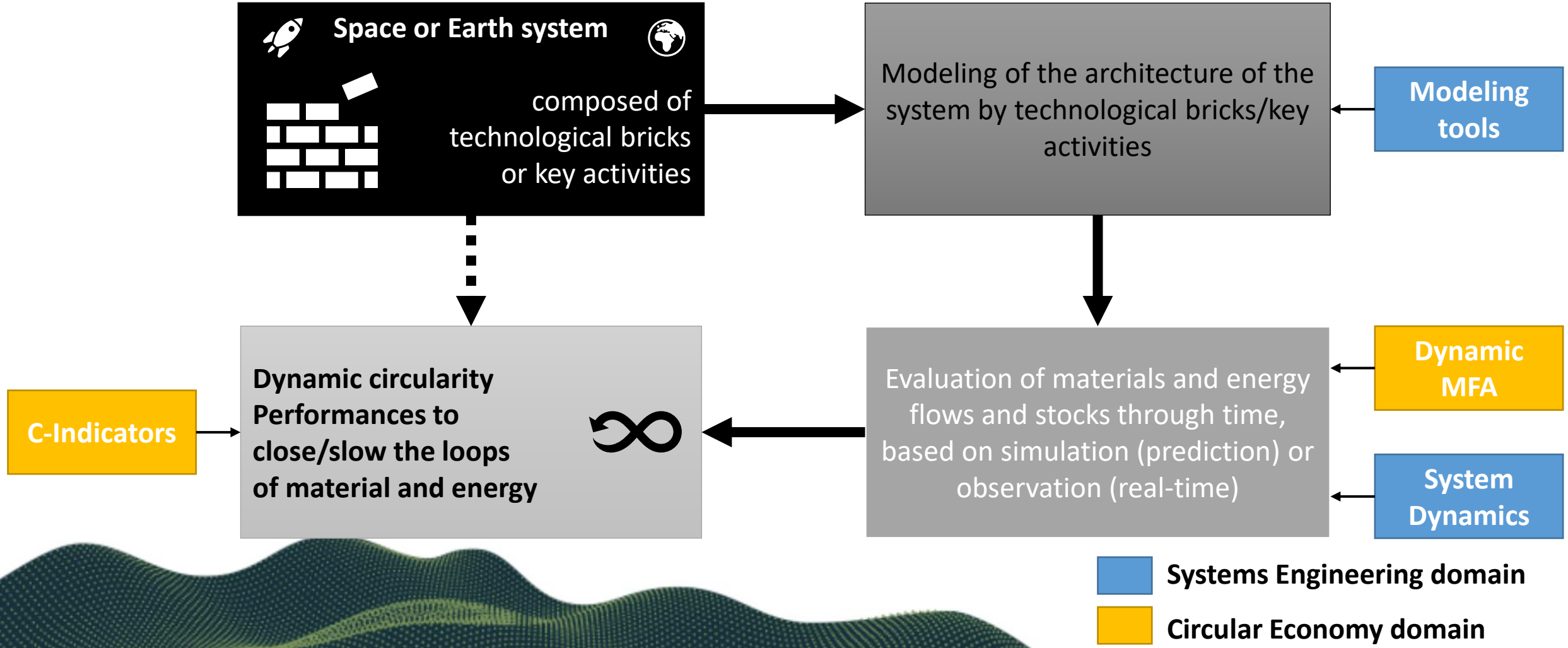
ENGINSOFT

Input / Output flow models

Static CFD models

- Temperature
- Pression
- Piping & Pneumatic

Towards a simulation platform for circularity performances



Perspectives to bridge the gap between Systems Engineering and Circular Economy

Systems Engineering

- Complex and heavy processes
- Necessary to design complex systems
- Still « reluctant » to successfully integrate environmental aspects
  - Most of the time mono-criteria or on a limited scope

Circular Economy

- Considers more and more complex systems
  - large value chains, territories, multi-stakeholders…
- Lacks of rigorous processes and tools when complexity increases
- Integration of tools like MFA, LCA, C-Indicators…

→Gather together experts from both disciplines to make complex engineered systems much more circular

→Simulation platform for circularity performances

→For space systems: foster collaborations within the MELiSSA ecosystem?

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THANK YOU.

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