
INTEGRATION
TECHNOLOGY
SYSTEM
AUTOMATION
INNOVATION
PROCESS
PERFORMANCE


Le CLUB Digital Engineering
Transition systémique : les forces en présence
Webinar
Mardi 18 octobre
9h30 - 12h30
Industrie et Services
Digital Engineering
Systematic
Paris Region Deep Tech Ecosystem


INTEGRATION
TECHNOLOGY
AUTOMATION
SYSTEM
INNOVATION
PROCESS
PERFORMANCE

Bienvenue !

Programme

- *9h30 – OUVERTURE*

  Philippe Mils – Co-Président Hub Digital Engineering – Business Developer Manager Thales R&T

- *9h40 – Retours d'expérience, état des pratiques :*
  - **CEREMA** Conception de la ville durable
  - **Eiris Conseil** – Conception de systèmes et systémique environnementale et sociétale

- *10h40 – Outils d'ingénierie des systèmes & Simulation*
  - **Dassault Système** System engineering et Sustainable Virtual Twin Experience

    CESAMES Jumeaux numériques systémiques : de quoi s'agit il ?
  - **Syscience** Analyse des risques induits par le changement climatique sur l'outil productif : Apport d'une approche système

- *11h40 – Conception de systèmes et systémique environnementale et sociétale – point de vue académique*
  - **INERIS** Evolution des systèmes industriels complexes : gestions des risques et enjeux environnementaux et sociétaux

- *12h00 – Échanges avec les participants*

Mot d’accueil

Philippe Mils

Co-Président Hub Digital Engineering
Business Developer Manager
Thales R&T

Retours d’expérience, état des pratiques

CEREMA Conception de la ville durable

Eiris Conseil – Conception de systèmes et systémique environnementale et sociétale

Conception de la ville durable

Jean-Louis SIX

Directeur Délégué au numérique

Centre d'études et d'Expertise sur les Risques, l'Environnement, la Mobilité et l'Aménagement

Merci de votre attention

Jean-louis.six@cerema.fr

Directeur Délégué au numérique

Questions / réponses

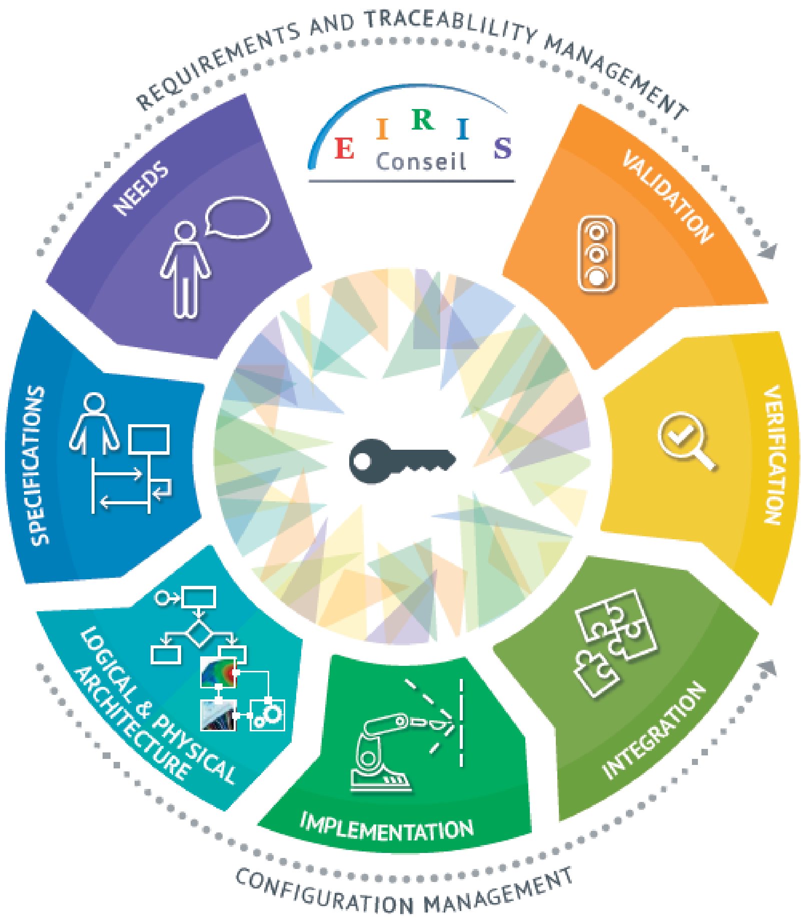
Conception de systèmes et systémique environnementale et sociétale

Françoise Caron

Fondatrice

Eiris Conseil

Tirer parti de l'ingénierie système



Une approche

pour la transition écologique,

Le rôle des PME

Transformations environnementales et sociétales

Webminaire System@tic

18 octobre 2022

EIRIS Conseil

eiris.fr

Transition écologique

Le Pôle des PME

- Enjeux et objectifs
- Les PME, des contributeurs actifs
- Les verrous à l'accélération
- Leviers et axes de solutions
- Pour conclure

ENJEUX ET OBJECTIFS

- Endiguer le réchauffement climatique.
- Assurer une autonomie alimentaire saine.
- Assurer une autonomie manufacturière durable.

- Objectif européen : réduction des émissions de CO_2, de 55% par rapport 1990, à d'ici à 2030
- Objectif français : réduction de consommation d'énergie, de 10% par rapport à 2018, en 2 ans à partir d'octobre 2022.

Tout en réindustrialisant les territoires.

LES PME, DES CONTRIBUTEURS ACTIFS

❑ Contributions directes :

PME innovantes dans les domaines « durables »

- ❑ Energie : hydrogène vert, photovoltaïque, ….
- ❑ Bâtiment : ciment décarboné,
- ❑ Agriculture durable et alimentation : irrigation, binage V2.0, ….
- ❑ Chimie biosourcée : alternative aux molécules issues de la pétrochimie
- ❑ Economie circulaire, recyclage industriel : transformation des plastiques

❑ Contributions indirectes :

Incluant aussi des PME de domaines traditionnels, parfois depuis plusieurs générations au travers de la reconception de

- ❑ Systèmes de production
- ❑ Systèmes approvisionnement, logistique, distribution, après-vente, …

LES VERROUS
A L'ACCÉLÉRATION DES CONTRIBUTIONS DES PME

❑ Feuilles de route européenne / nationale

- ❑ Définition et communication
  - ❑ Priorités claires et critères d'évaluation(exigences) ;
  - ❑ Calendrier et jalons ;
  - ❑ Responsabilités clé.

- ❑ Mise en œuvre et suivi
  - ❑ Constitution des structures de pilotage ;
  - ❑ Financement ;
  - ❑ Procédures d'évaluation et de réajustement.

LES VERROUS
A L'ACCÉLÉRATION DES CONTRIBUTIONS DES PME

❑ Organisation de la recherche appliquée selon le mille-feuille territorial

- Renforcée par l'organisation à la fois thématique et régionales :
  - des pôles de compétitivité
  - des IRT et ITE

- Lisibilité des financements au travers des couches du mille-feuille :

  Nationale, départementale, métropoles, agglomérations de communes.
  - financements publics et publics/privés.
- Accès aux financements strictement privés (Private Equity, Grands groupes)

LES BESOINS DES PME CONTRIBUTRICES

❑ PME innovantes : conception de systèmes « à faire »

- ❑ Pour des contextes d'usage nouveaux et/ou basés sur de nouvelles technologies et matériaux.

Besoins d'entreprises innovantes : preuves de concept, passage à l'échelle, …

☺ Il existe des solutions (Pôles, IRT, FabLabs, …..) déjà malgré les verrous cités.

❑ Pour toutes

- ❑ Conception, reconception de systèmes « pour faire »
  - ❑ Dans une perspective de sobriété : énergie, eau, M2, …
- ❑ Modification du système « à faire »

Besoins d'objectifs « eco-conception » , de référentiels, de support (traçabilité, compromis)

😐 Solutions à construire

LEVIERS ET AXES DE SOLUTION

❑ Leviers

- ❑ Les solutions existantes pour les entreprises innovantes peuvent être adaptées.
- ❑ Le maillage des structures territoriales à destination des PME (CCI, réseaux d'entrepreneurs, …) peut être utilisé pour sensibiliser, informer, former.

❑ Axes de solution

- ❑ Considérer que toute entreprise, même dans les domaines les plus traditionnels, est nécessairement innovante.
- ❑ Déverrouiller les frontières intra-nationales et impliquer les organisations territoriales dans les projets.
- ❑ Croiser les leviers en en tirant les meilleurs partis des différents domaines responsabilités.

❑ Et le pôle system@tic et ses adhérents ?

- ❑ Pourquoi ne pas aller à la rencontre de PME dites « traditionnelles » ?

- ❑ Leur faire connaître les outils du pôle en support à l'innovation :

Complémentaires à ceux des réseaux locaux.

- ❑ Les aider à franchir un pas et les accompagner pour devenir acteurs de projets nationaux ou européens :
  - ❑ Collaboratifs et « circulaires »
  - ❑ Impliquant aussi des organisations territoriales.

Questions / réponses

Outils d'ingénierie des systèmes & Simulation

Dassault Système System engineering et Sustainable Virtual Twin Experience

CESAMES Jumeaux numériques systémiques : de quoi s'agit il ?

Syscience Analyse des risques induits par le changement climatique sur l'outil productif : Apport d'une approche système

System engineering et Sustainable Virtual Twin Experience

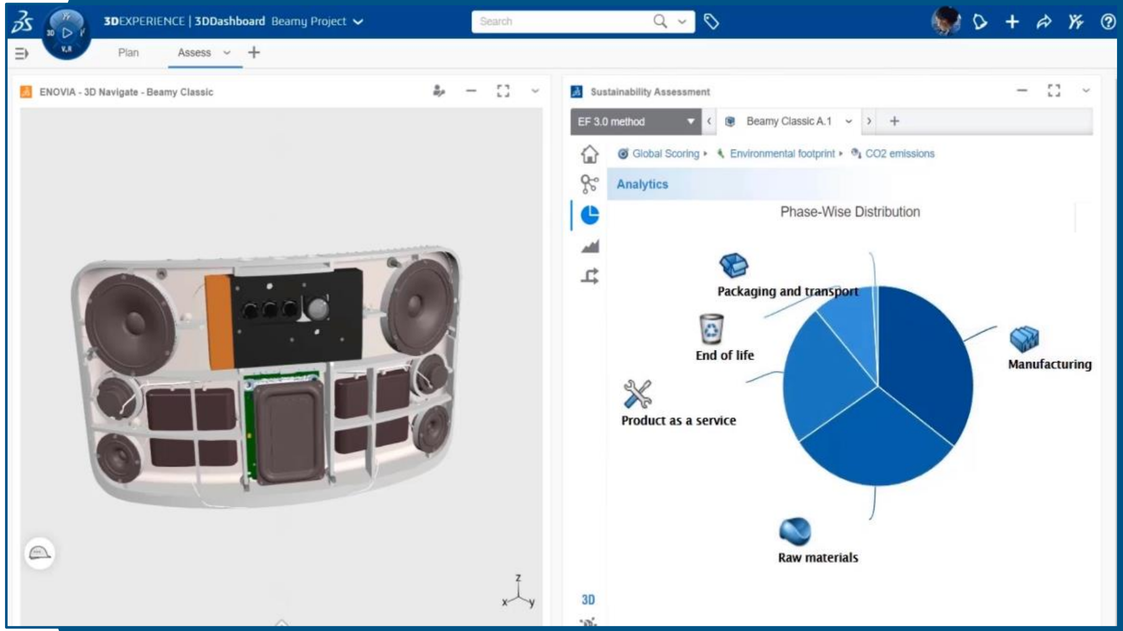
Guillaume Belloncle

CATIA - Senior Strategic Planning Analyst

Dassault Système

Imaginer et développer des entreprises, des produits et des services performants, durables et résilients avec le jumeau numérique

Guillaume BELLONCLE
CATIA | Strategy Senior Analyst
gxe@3ds.com
@gbelloncle



DASSAULT SYSTEMES | The 3DEXPERIENCE® Company

DASSAULT SYSTÈMES

> ***DASSAULT SYSTÈMES** PROVIDES BUSINESS & PEOPLE WITH **3D**EXPERIENCE UNIVERSES TO IMAGINE SUSTAINABLE INNOVATIONS CAPABLE OF **HARMONIZING PRODUCT**, **NATURE** AND **LIFE**.*

The **3DEXPERIENCE** Company

- € 4.9 billion revenue
- 290’000 Enterprise Customers
- 26 million Users
- 20’000 passionate Employees
- 12’000 Partners

Delivering software **solutions for 12 industries**

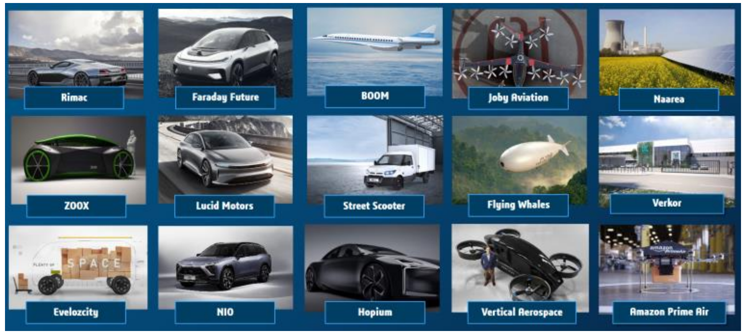
- Transportation & Mobility
- Aerospace & Defense
- Consumer Packaged Goods - Retail
- Marine & Offshore
- Industrial Equipment
- High Tech
- Home & Lifestyle
- Architecture, Engineering & Construction
- Infrastructure, Energy & Materials
- Business Services
- Public Services
- Life Sciences & Healthcare

Collaborating with **Industry Leaders…**

RENAULT Passion for life | JAGUAR | LAND ROVER | BMW | HONDA | TOYOTA
DASSAULT AVIATION | AIRBUS | BOEING | SAFRAN
BOSCH | ERICSSON | eDF | BOUYGUES

…

…& **Industry Shakers**

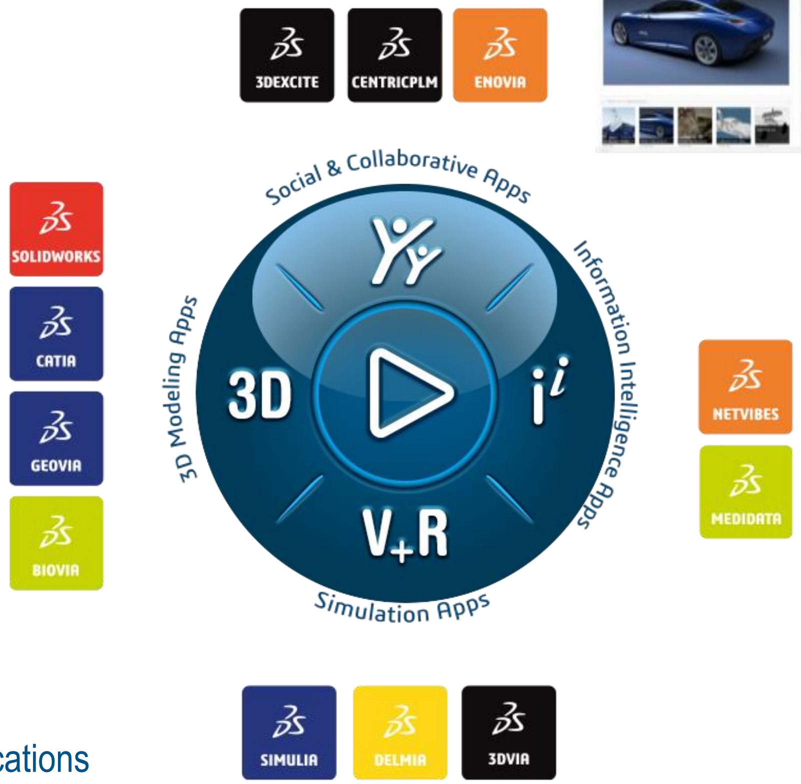


DASSAULT SYSTEMES

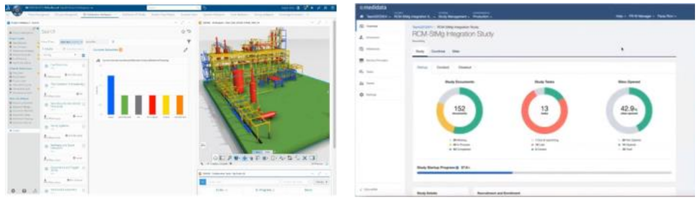
Accelerate Innovation with the 3DEXPERIENCE platform

SOCIAL & COLLABORATIVE Applications

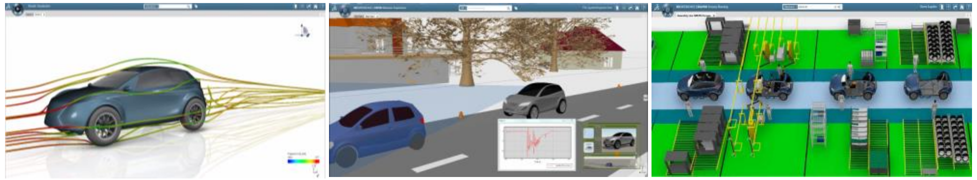
MODELING Applications



INFORMATION INTELLIGENCE Applications



VIRTUAL + REAL Simulation Applications



3DS SUSTAINABILITY COMPASS

2025 DETAILED TARGETS

EXPERIENCE

THE CHANGE

WE STRIVE TO "WALK THE TALK" AND EMBED SUSTAINABILITY IN EVERYTHING WE DO.

- **SCIENCE-BASED** carbon emissions targets & **CARBON NEUTRAL by 2040** target and a **5 ton CO2/FTE** goal* (-38% vs. 2018)
- **40% of executive*** & 30% of people manager **roles held by women**
- **95% of employees** having completed **Ethics training**
- **85% employee pride & satisfaction** score*

HARMONIZE

THE PORTFOLIO

WE FOCUS ON PROVIDING THE TOOLS AND THE INSPIRATION FOR OUR CUSTOMERS TO INNOVATE SUSTAINABLY.

- **2/3 of 3DS' new revenue** from solutions with sustainability impact
- Life Cycle Assessment integrated in **3D**EXPERIENCE by 2022

COLLABORATE

WITH STAKEHOLDERS

WE AIM TO WORK IN PARTNERSHIP WITH CUSTOMERS, EMPLOYEES, AND OTHER STAKEHOLDERS.

- Engage **5,000 stakeholders** (employees, suppliers, clients, NGOs...)
- Hold a **sustainable innovation event** every year

AWARDS

Forbes: WORLD'S TOP 50 BEST EMPLOYERS (#19, 2021)

CDP: CARBON DISCLOSURE PROJECT A- SUPPLIER ENGAGEMENT RATING (2021)

S&P Global: ENTERED DOW JONES SUSTAINABILITY INDEX: #5 IN SOFTWARE SECTOR (2021)

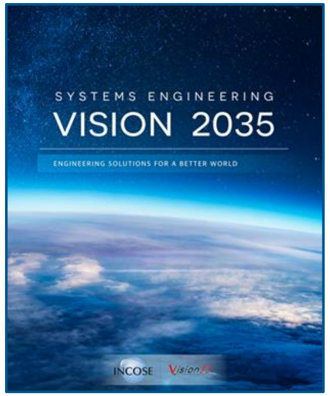
OUR MEMBERSHIPS

Ellen MacArthur Foundation; BSR; GeSI Global e-Sustainability Initiative; European Green Digital Coalition; Dow Jones Sustainability Indexes; UN Global Compact

* These targets are integrated into the variable remuneration of 3DS' CEO

INCOSE Vision 2035 | Mega Trends

INCOSE



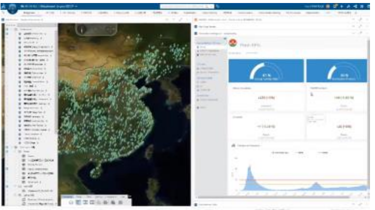
Source: INCOSE,
www.incose.org/about-systems-engineering/se-vision-2035

- **Change** is the norm, it is **accelerating**
- Need for a **science-based** approach
- From Product to **Experience** with new usage & business models
- **Systems Engineering adoption** across all industries

Systems engineering is the only practice looking after **stakeholders needs** to maximize the **value (business / environmental)**, while minimizing **risks**

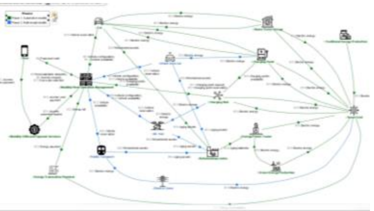
Sustainability is a Systemic Challenge

Source: UN



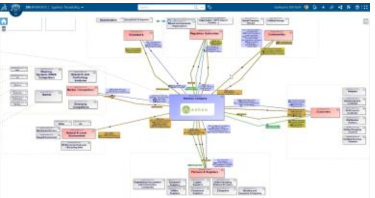
Territories
Cities

- How to ensure **2030 / 2050 agenda**?
- How to design & operate **Sustainable Cities**?



Value networks

- How to have a **resilient and sustainable Supply chain**?
- How to put **in place circular interactions** with my ecosystem?

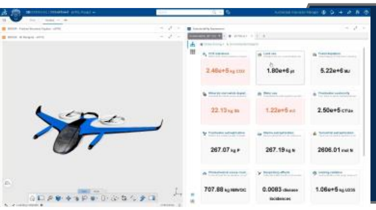


Company

- How to **comply with new regulations** for my industry?
- How to **reinvent my business model** to make the most of circular economy **potential value**?
- How to communicate with facts on **my engagement** to reduce my footprint to **consumers and investors and employees** and deliver the promised results?

Manufacturing Systems
Infrastructures

- How to **design circular manufacturing** systems and infrastructures?
- How to **operate a resilient & sustainable** manufacturing system?
- How to **empower front line workers** to continuously improve operations?



Products, Materials
Products in operation

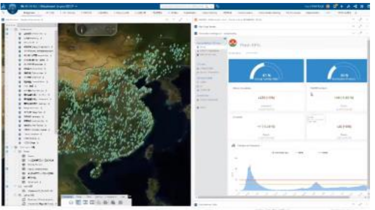
- How to **integrate new technologies** in my value stream to **optimize** all my product lifecycle
- How to take into account **end of life** (dismantling, recycling, reuse,…) during design phase?
- How to **assess** end to end footprint & how to **improve it during usage phase**?

"All models are wrong, but some are useful."
George Box

https://en.wikipedia.org/wiki/All_models_are_wrong

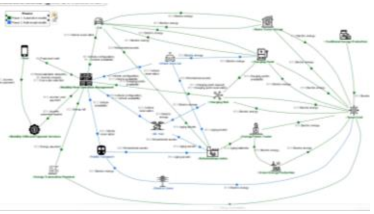
Sustainability is a Systemic Challenge

Source: UN



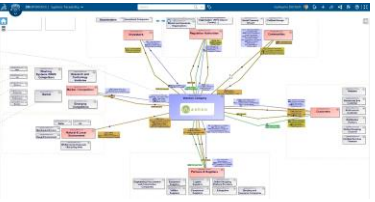
Territories
Cities

- How to ensure **2030 / 2050 agenda**?
- How to design & operate **Sustainable Cities**?



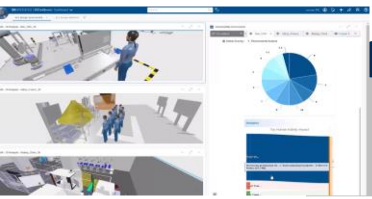
Value networks

- How to have a **resilient and sustainable Supply chain**?
- How to **put in place circular interactions** with my ecosystem?



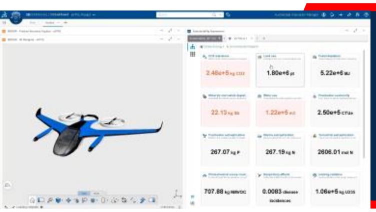
Company

- How to **comply with new regulations** for my industry?
- How to **reinvent my business model** to make the most of circular economy **potential value**?
- How to communicate with facts on **my engagement** to reduce my footprint to **consumers and investors and employees** and deliver the promised results?



Manufacturing Systems
Infrastructures

- How to **design circular manufacturing** systems and infrastructures?
- How to **operate a resilient & sustain**able manufacturing system?
- How to **empower front line workers** to continuously improve operations?



Products, Materials
Products in operation

- How to **integrate new technologies** in my value stream to **optimize** all my product lifecycle
- How to take into account **end of life** (dismantling, recycling, reuse,…) during design phase?
- How to **assess** end to end footprint & how to **improve it during usage phase**?

Scope of today demonstrations

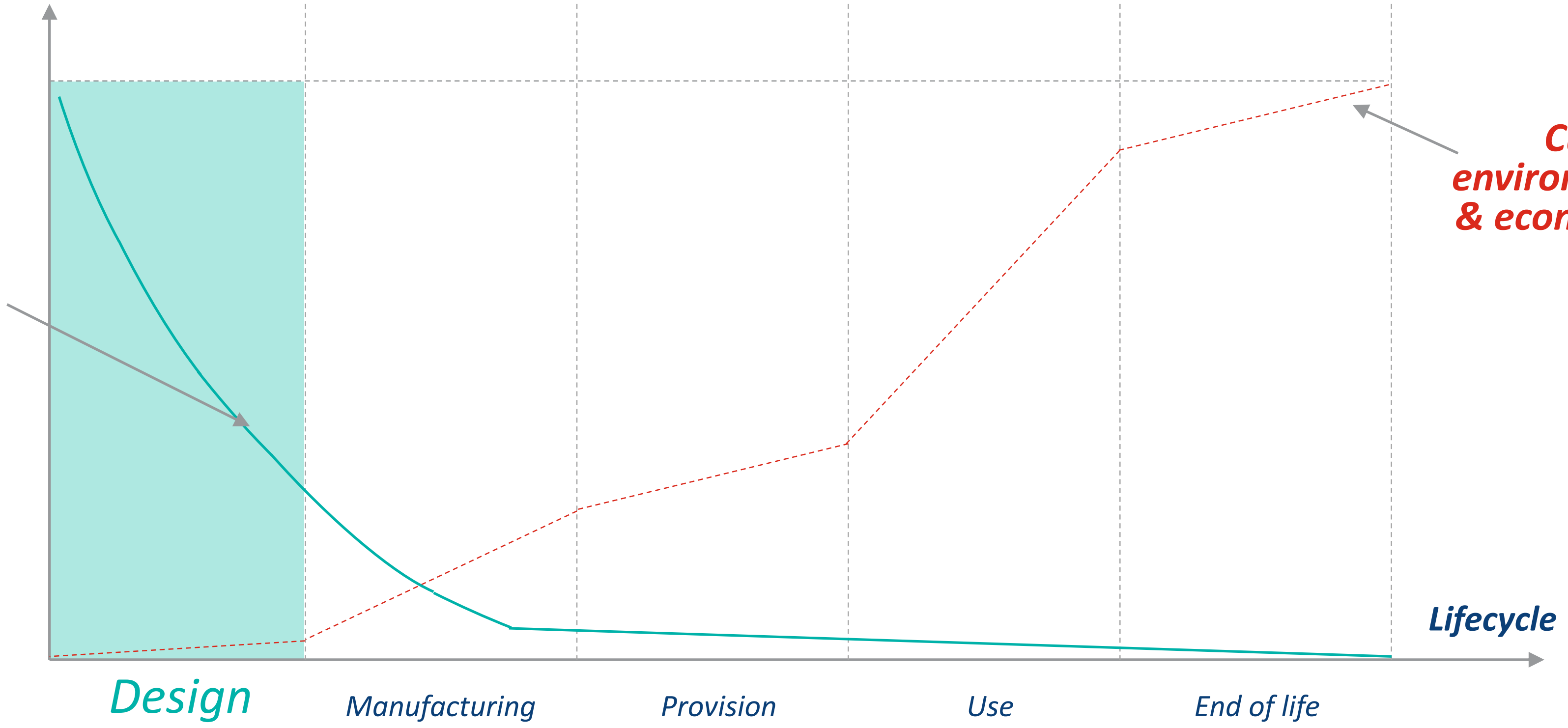
SUSTAINABILITY BY-DESIGN

Design choices widely influence impacts of products along full lifecycle

100% of total impact

Influence on environmental, social & economical impact

Up to 80% 
of products' environmental impacts are determined at the design phase



Cumulated environmental, social & economical impact

Design for sustainable material sourcing
Design for sustainable manufacturing

Design for optimized logistics

Design for re-use, for assembly & disassembly

Design for end-of-life
Design for waste management

….

Sources: *Designing for the circular economy,* Martin Charter ; 80% of impact determined at design phase according to the EU commission
https://www.mdpi.com/1996-1073/14/12/3469/htm ; https://www.researchgate.net/figure/Evolution-of-the-sustainability-impact-of-the-possibility-of-influencing-it-of-the_fig1_335834874

Life Cycle Analysis for Products & Processes

WHAT

Multi-criteria analysis

1 Damage to **Human Health**
- Respiratory effects
- Photochemical ozone creation
- Ionising Radiation
- Ozone layer depletion
- Carcinogenic effects
- Non-Carcinogenic effects
- CO_2 Emissions

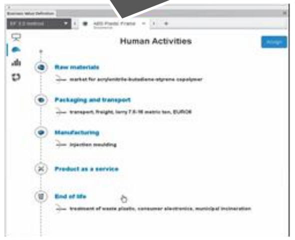
2 Damage to **Ecosystems**
- Water use
- Freshwater Ecotoxicity
- Freshwater Eutrophication
- Terrestrial Eutrophication
- Acidification
- Land Use
- Marine Eutrophication

3 Damage to **Resource availability**
- Fossil Depletion
- Minerals and metals depletion

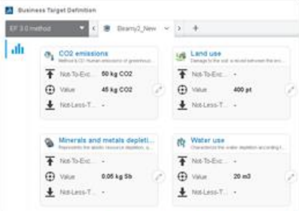
+ companies specific criterias

Holistic analysis

HOW



Specify targeted material and manufacturing process on part or assemblies



Compare against objectives

Get environmental impact calculation from ecoinvent database

DASSAULT SYSTEMES

VIRTUAL TWINS' POTENTIAL

SUSTAINABILITY IMPACT QUANTIFIED

FIVE USE CASES ALONE CAN UNLOCK COMBINED ADDITIONAL BENEFITS

CONSTRUCTION & CITIES	Reduce energy consumption in buildings by 30 - 80%.
CONSUMER PACKAGED GOODS	Eco-design products to reduce 80% of their impact.
TRANSPORTATION AND MOBILITY	Accelerate the time to market for the next generation of mobility solutions.
LIFE SCIENCES	Reduce waste, pollution, and resource consumption in pharmaceutical manufacturing.
HIGH TECH	Electronics: Embed circular economy principles to address the growing problem of e-waste.

READ THE FULL WHITE PAPER HERE

accenture DASSAULT SYSTEMES

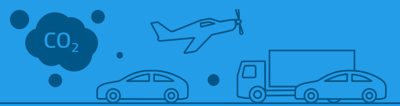
TOTAL:

$1.2 trillion
Of economic value

7.5 Gt CO_2e
Of emissions reductions

By 2030
based on these five use cases alone

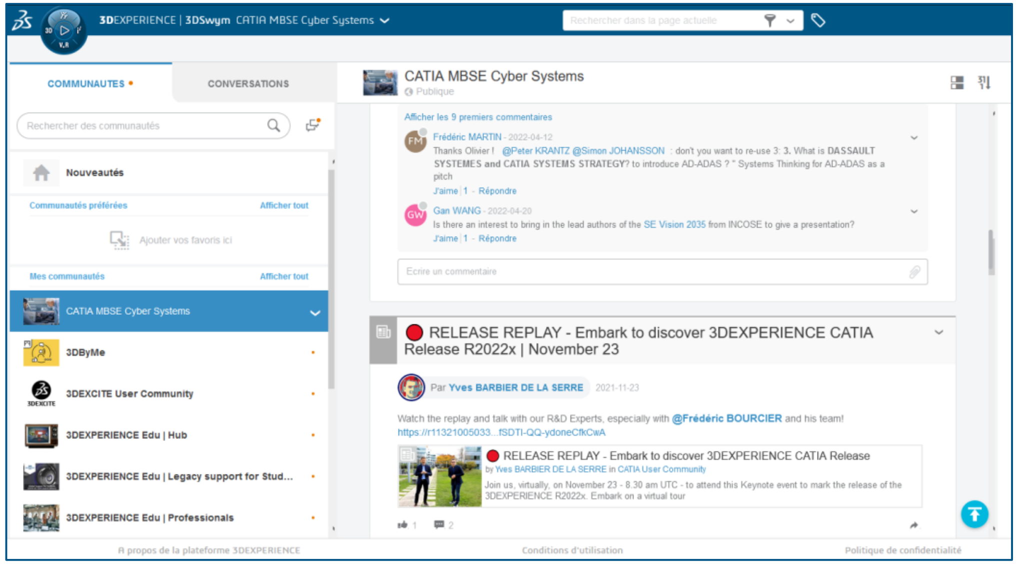
7.5 Gt CO_2e emissions

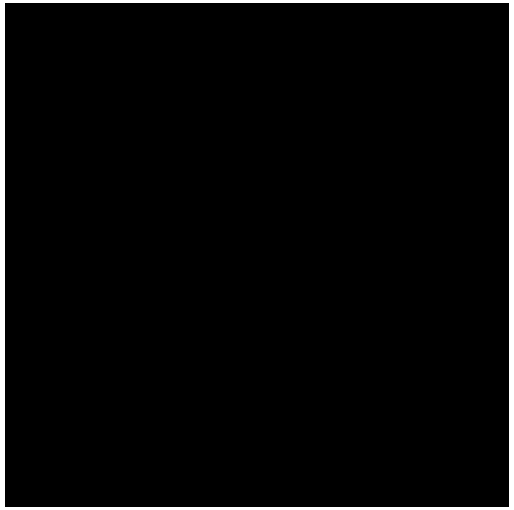


= Global yearly emissions of the transport sector

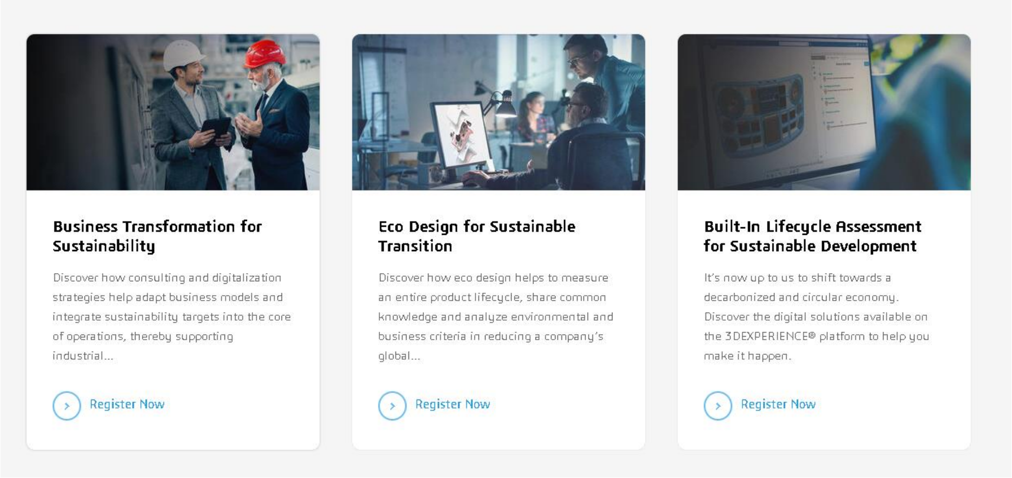
ADDITIONAL RESOURCES

[CATIA MBSE Community]





[https://www.3ds.com/sustainability/]



[https://events.3ds.com/built-sustainability-economic]

Questions / réponses

Jumeaux numériques systémiques : de quoi s’agit il ?

Daniel Krob

Président

CESAMES

Systemic digital twins for mastering complex enterprise operations & strategy

Daniel KROB (INCOSE Fellow)

June 2022

WorldLab

Agenda

1. **Systemic Intelligence Group**
2. Why systemic digital twins?
3. What is a systemic digital twin?
4. An illustrating example: a submarine mine
5. Questions & answers

CESAMES

Systemic Intelligence Group in a nutshell

Core competences

- Systems architecture
- Enterprise architecture & transformation
- Iterative & collaborative systems engineering
- Agile@scale architecture
- Product lines architecture
- Model-based systems engineering (MBSE)
- **Systemic digital twins**

Offers
Transformation support
Modeling expertise
Systemic digital twins
Coaching & training

Team
30
architects

Income
6 M€
2021

Offices
Paris
Toulouse
Shanghai

Creation
Spin-off - 2011

Partners
INCOSE • Systematic Paris Region Deep Tech Ecosystem • Dassault Systèmes

On-the-job training programs
AIRBUS GROUP • ARIANE GROUPE • NISSAN • RENAULT • SAFRAN • SCHNEIDER ELECTRIC • STELLANTIS

CESAM method
≈10,000
trained professionals for 10 years

Community
CESAM COMMUNITY
Our systems architect community

Events
- CSD&M Paris & Beijing
- Industrial Enterprise Architecture Day
- Top executive club

LinkedIn
≈ 10,000
followers

We are a **spin-off** of the industrial chair "Engineering of complex systems" of Ecole Polytechnique. We are a part of CESAMES group which is specialized in **systems architecting & engineering**, a domain that proposes modeling & simulation techniques that aims at better mastering industrial complexity. We disseminated **innovative methods & tools** in this area for the last 10 years within various industries (aeronautics, automotive, construction, defense, energy, high tech, railway, space), mainly in China, France, Germany and Japan.

Our customers

Aeronautics
AIRBUS Commercial Aircrafts – AVIC – COMAC – SAFRAN Group

+ CORAC, Daher Dassault Aviation

Automotive
NISSAN – GROUPE RENAULT – STELLANTIS – Valeo

+ Mitsubishi

Energy
EDF – framatome – Schneider Electric

+ Rolls Royce, Technip

Defense & space
AIRBUS Defence & Space – AIRBUS Helicopters – arianeGroup – SAFRAN Electronics & Defense

+ Dassault Aviation, Kawasaki, Thalès

Construction
Groupe ADP – Bouygues Construction – OTIS – somfy

+ Eiffage, Saint-Gobain, Vinci

Electronics & services to industry
fives – HUAWEI – IDEMIA – SoftBank Robotics

+ A3BC, Dassault Systèmes, PTC

Innovation & public services
dgac – Premier ministre, Secrétariat général pour l'investissement – SystemX

+ Caisse des dépôts, Opéra National de Paris, Pôle Emploi

Railway
ALSTOM - RATP

Engineering
Alten – Altran – Assystem – Egis – Vulcain Ingénierie

Health
Horiba

Mines
Debswana

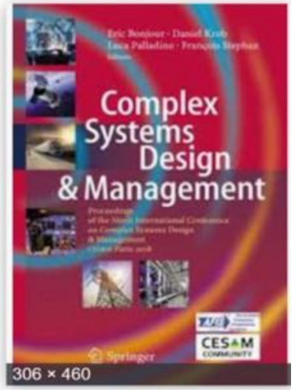
Bank
Crédit Agricole – LCL – Société Générale

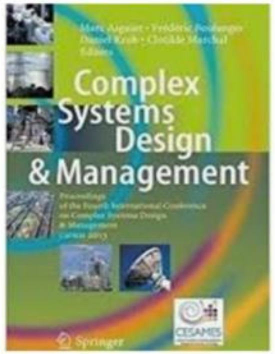
Insurance
AG2R La Mondiale – AXA – COVEA

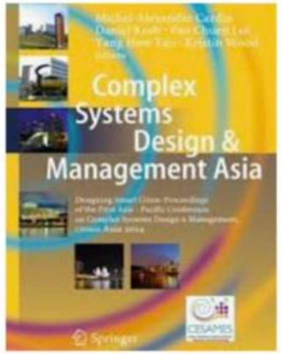
Services
Carrefour – TF1

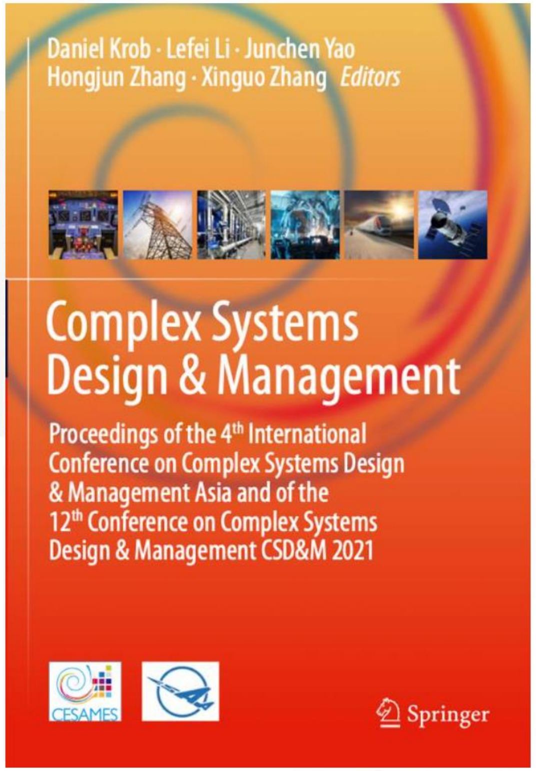
The current industrial customers of CESAMES group

Our academic & professional network



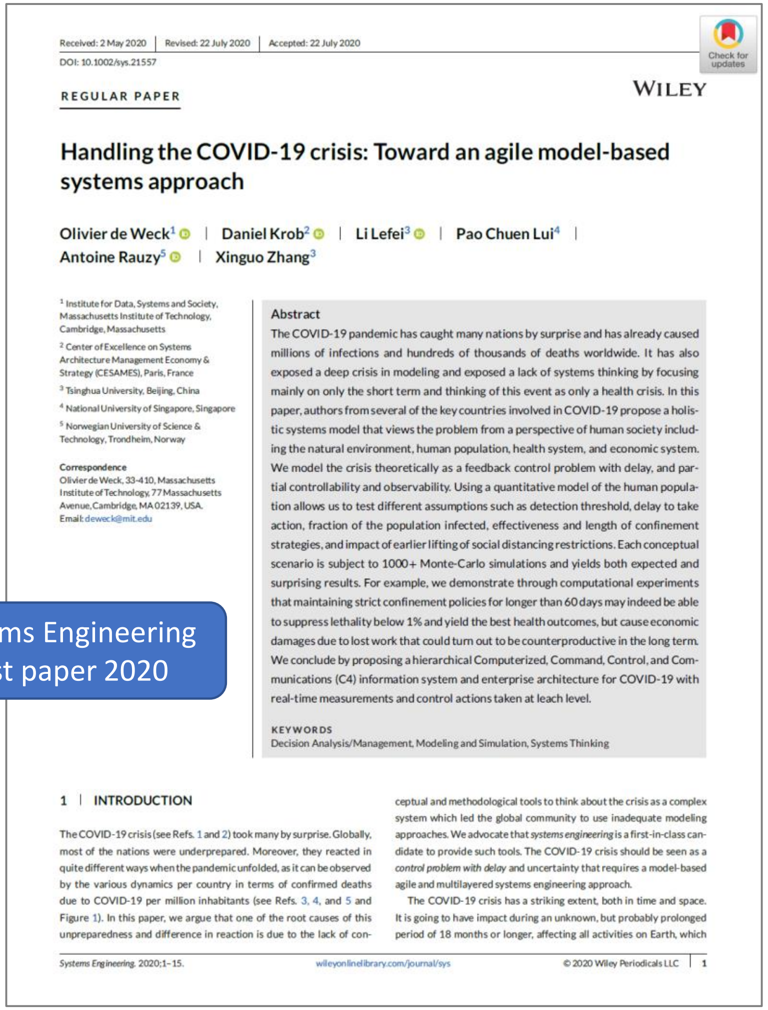






Our network is especially animated through the **academic & professional events** that we are regularly organizing in France and Asia, the most important one being the international conference on **Complex Systems Design & Management** (CSD&M), that we already organized each year in Beijing, Paris and Singapore during the last 12 years.

The starting point of our journey


Received: 2 May 2020 | Revised: 22 July 2020 | Accepted: 22 July 2020
DOI: 10.1002/sys.21557

REGULAR PAPER

WILEY

Handling the COVID-19 crisis: Toward an agile model-based systems approach

Olivier de Weck[1] | Daniel Krob[2] | Li Lefei[3] | Pao Chuen Lui[4] | Antoine Rauzy[5] | Xinguo Zhang[3]

[1] Institute for Data, Systems and Society, Massachusetts Institute of Technology, Cambridge, Massachusetts
[2] Center of Excellence on Systems Architecture Management Economy & Strategy (CESAMES), Paris, France
[3] Tsinghua University, Beijing, China
[4] National University of Singapore, Singapore
[5] Norwegian University of Science & Technology, Trondheim, Norway

Correspondence
Olivier de Weck, 33-410, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA.
Email: deweck@mit.edu

Abstract
The COVID-19 pandemic has caught many nations by surprise and has already caused millions of infections and hundreds of thousands of deaths worldwide. It has also exposed a deep crisis in modeling and exposed a lack of systems thinking by focusing mainly on only the short term and thinking of this event as only a health crisis. In this paper, authors from several of the key countries involved in COVID-19 propose a holistic systems model that views the problem from a perspective of human society including the natural environment, human population, health system, and economic system. We model the crisis theoretically as a feedback control problem with delay, and partial controllability and observability. Using a quantitative model of the human population allows us to test different assumptions such as detection threshold, delay to take action, fraction of the population infected, effectiveness and length of confinement strategies, and impact of earlier lifting of social distancing restrictions. Each conceptual scenario is subject to 1000+ Monte-Carlo simulations and yields both expected and surprising results. For example, we demonstrate through computational experiments that maintaining strict confinement policies for longer than 60 days may indeed be able to suppress lethality below 1% and yield the best health outcomes, but cause economic damages due to lost work that could turn out to be counterproductive in the long term. We conclude by proposing a hierarchical Computerized, Command, Control, and Communications (C4) information system and enterprise architecture for COVID-19 with real-time measurements and control actions taken at leach level.

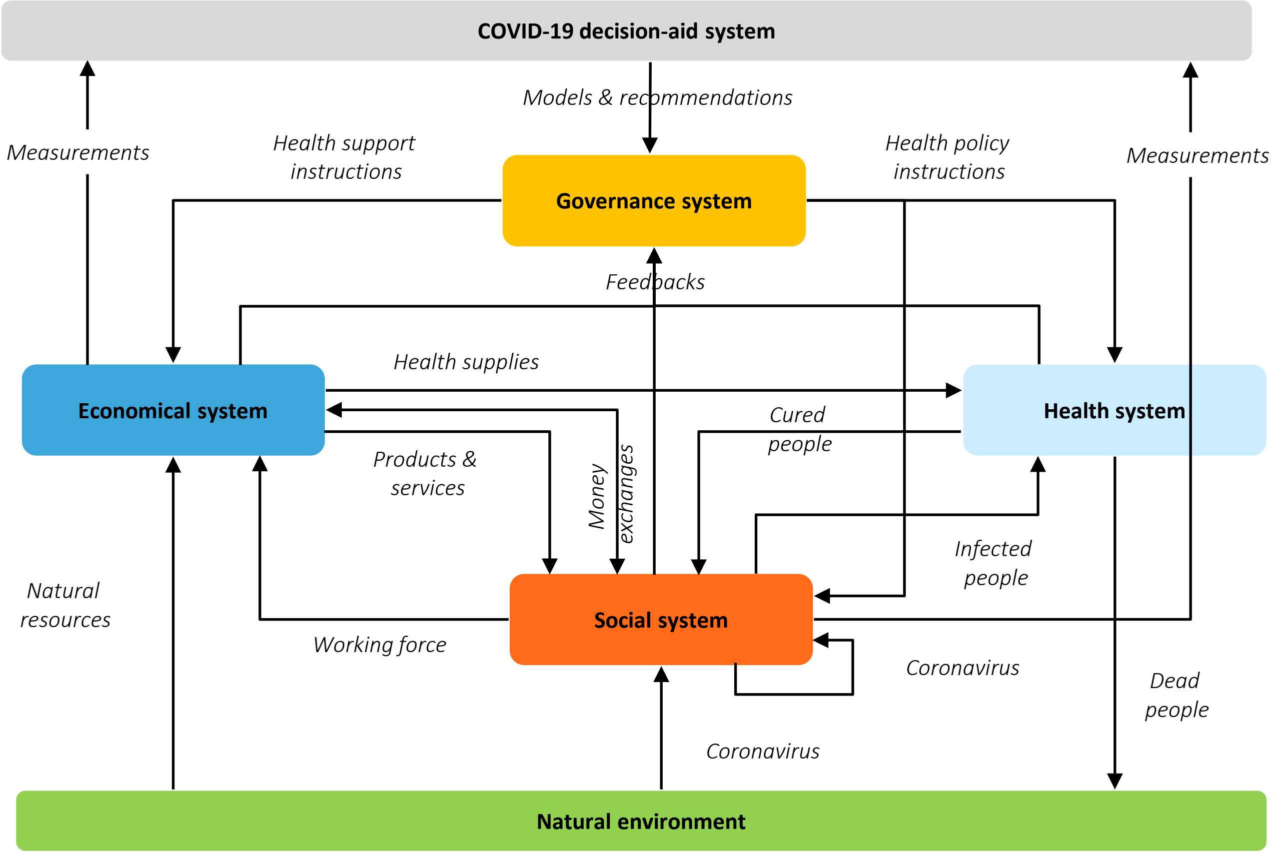
KEYWORDS
Decision Analysis/Management, Modeling and Simulation, Systems Thinking

1 | INTRODUCTION

The COVID-19 crisis (see Refs. 1 and 2) took many by surprise. Globally, most of the nations were underprepared. Moreover, they reacted in quite different ways when the pandemic unfolded, as it can be observed by the various dynamics per country in terms of confirmed deaths due to COVID-19 per million inhabitants (see Refs. 3, 4, and 5 and Figure 1). In this paper, we argue that one of the root causes of this unpreparedness and difference in reaction is due to the lack of conceptual and methodological tools to think about the crisis as a complex system which led the global community to use inadequate modeling approaches. We advocate that *systems engineering* is a first-in-class candidate to provide such tools. The COVID-19 crisis should be seen as a *control problem with delay* and uncertainty that requires a model-based agile and multilayered systems engineering approach.

The COVID-19 crisis has a striking extent, both in time and space. It is going to have impact during an unknown, but probably prolonged period of 18 months or longer, affecting all activities on Earth, which

Systems Engineering best paper 2020



A **seminal paper** where we proposed a **systemic digital twin approach** for modeling the world in the covid-19 crisis context

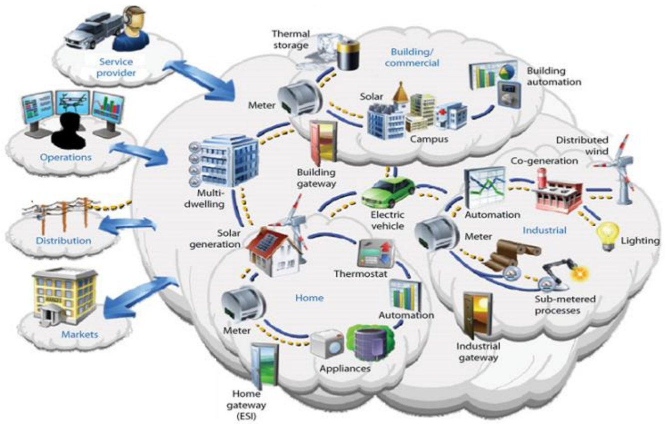
Agenda

1. Systemic Intelligence Group
2. **Why systemic digital twins?**
3. What is a systemic digital twin?
4. An illustrating example: a submarine mine
5. Questions & answers

CESAMES

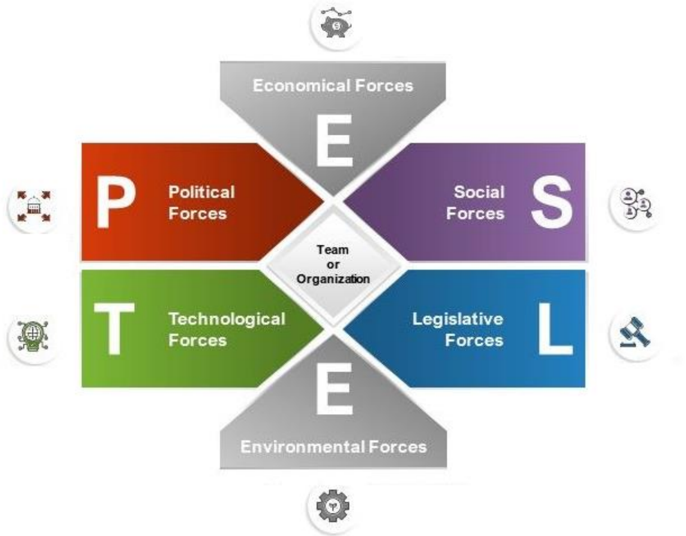
The context: industry has to manage more & more complexity (1/2)

Complex supply chains



Complex operations and maintenance

Complex industrial systems

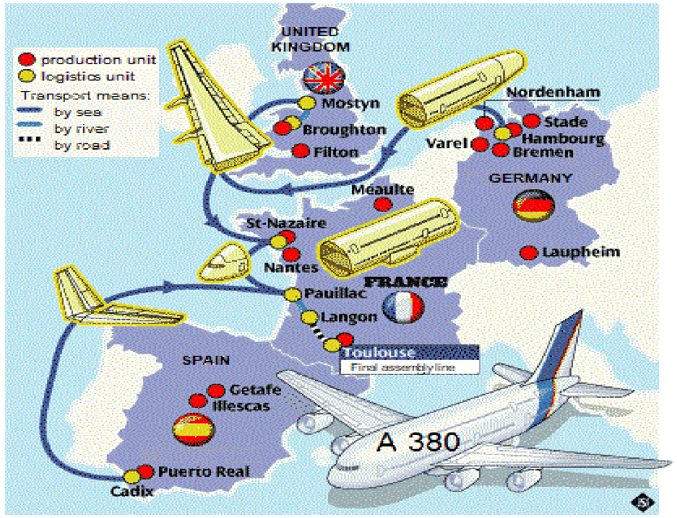


Complex environment

Modern industries are permanently dealing with many **complex internal & external interdependent systems**. They shall of course manage **complex operational systems** such as their supply chain, their production systems, their distribution systems, their customer operations, their maintenance systems, etc., but they must also take into consideration **complex economical, political, social, technological, legal and environmental constraints** from a tactical and strategic perspective.

The context: industry has to manage more & more complexity (2/2)

Product



Industrial company

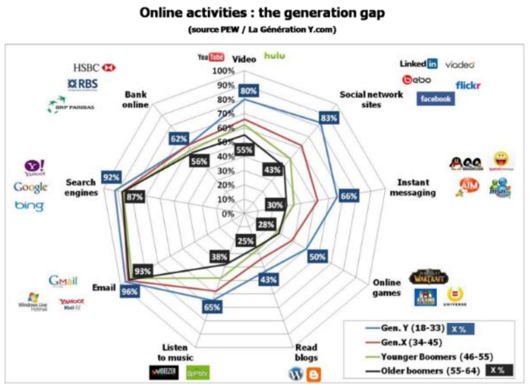
Economic sector

Global economy

Industrial optimization can moreover be approached at **several systemic scales**: that of the **product**, that of the **industrial company** that designs it, that of the associated **economic sector** and that of the **economy as a whole**, and each has its own difficulties. Managing and integrating smoothly these different scales appear to be a **key difficulty**.

CESAMES

The issue: how to be sure to take the right decisions?



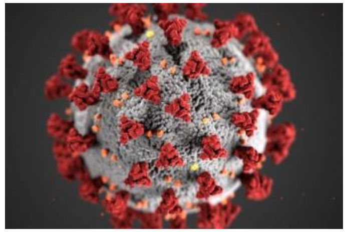
Change of consumption behaviors

Sustainable development goals

Economic uncertainty

Increase of regulations

Energetic transition challenge



Covid-19 crisis

In such complex environments, being able to **take the right operational & strategic industrial decisions** becomes key!

CESAMES

The landscape: industrial manufacturing & operations

Aircraft operators

Automotive fleet operators

Complex building operators

Energy operators

Logistics systems

Railway operators

Systemic digital twins are intended to support **industrial manufacturing & operations** in various domains.
Our initial domain of applications appears to be **logistics.**

Agenda

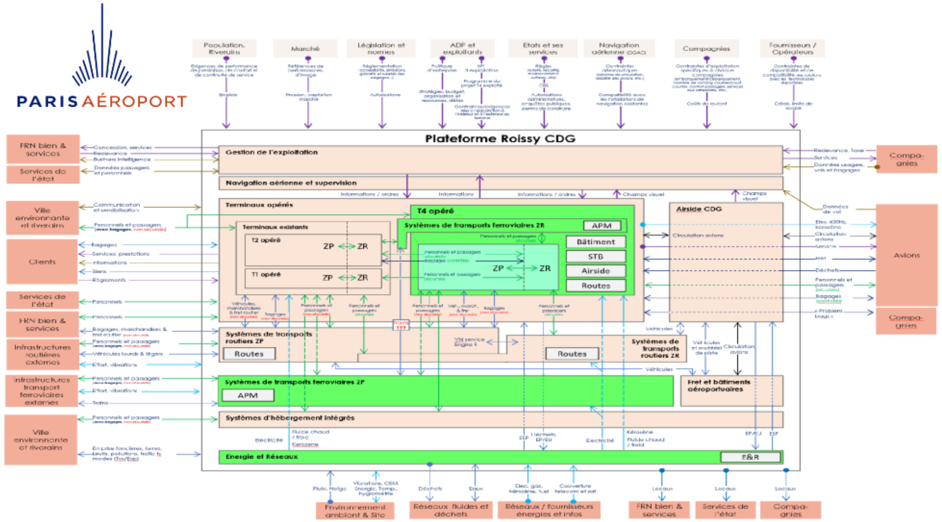
1. Systemic Intelligence Group
2. Why systemic digital twins?
3. **What is a systemic digital twin?**
4. An illustrating example: a submarine mine
5. Questions & answers

CESAMES

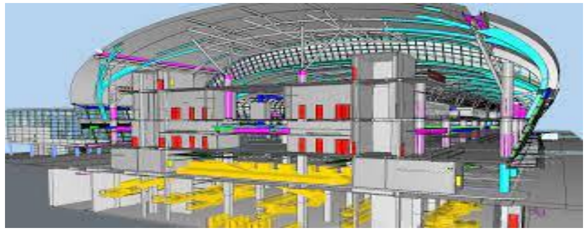
Systemic digital twin: a functional paradigm

IOT & RFID infrastructure

Smart devices



Enterprise business processes



Digital mock-ups

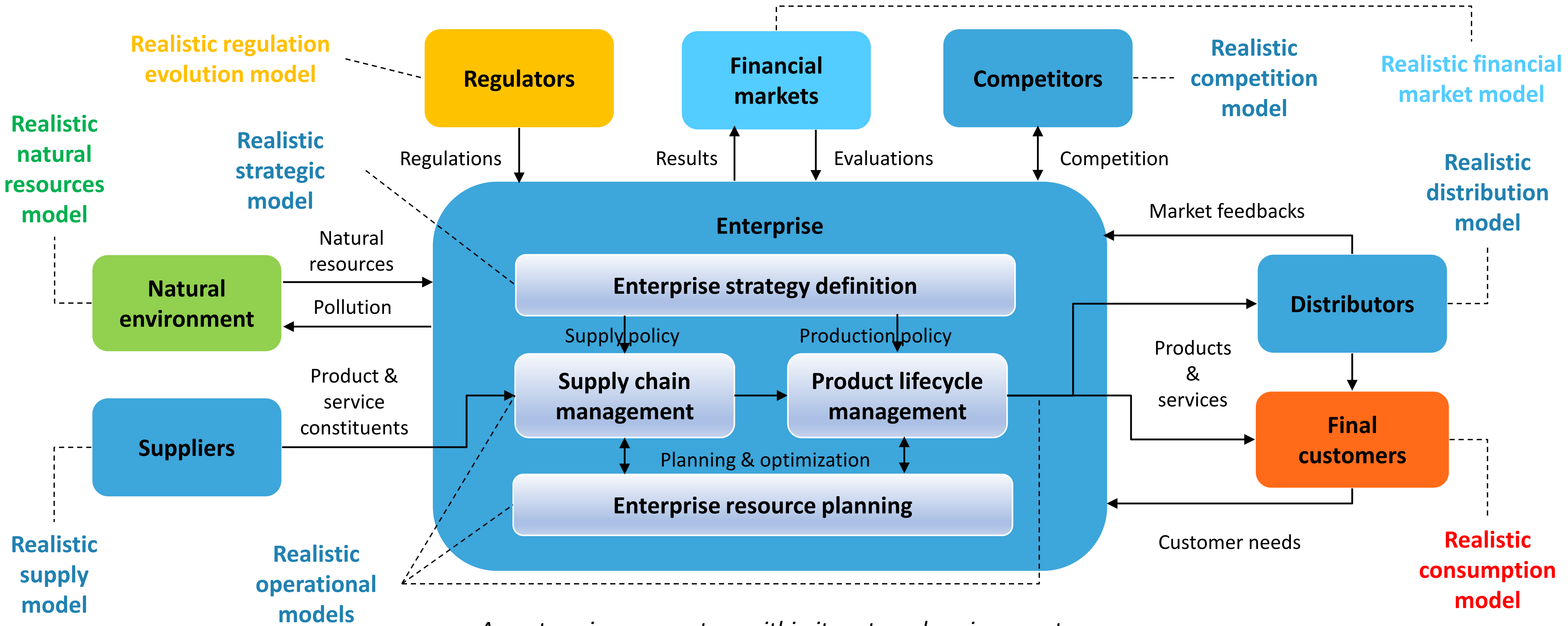
Building Information Modeling (BIM)

Our digital twin philosophy where enterprise business processes are at the core of a digital twin

All **existing digital twin technology** that are proposed by the market (e.g. Ansys, Bosch, Dassault Systèmes, PTC, Siemens, etc.) focuses either on **data-related infrastructure** or on **geometric representations**. We do believe that this is not the good point of view and that one must focus on **enterprise business processes**: a digital twin shall indeed be able to **model & simulate the behavior of an enterprise**, starting from operational data and ending by enriching decision dashboards or digital mock-ups, which put enterprise models at the core of a digital twin. This is why we took an **enterprise architecture behavioral approach** – based on formal modeling to support simulation by design – which is our key difference with respect to existing digital twin technology.

CESAMES

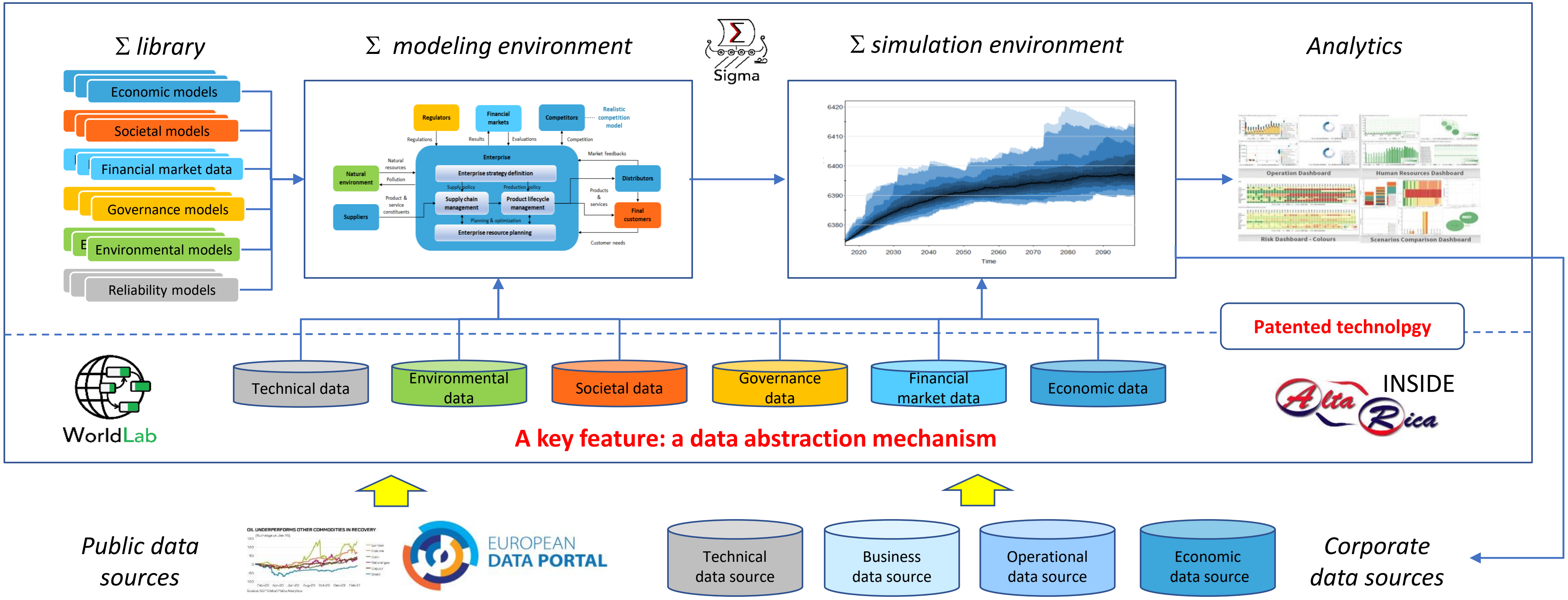
Our approach: a systemic vision to address enterprise complexity



An enterprise as a system within its external environment

To address enterprise complexity, our **approach** is based on an **unified enterprise systemic vision** that can support **operational & strategic analyses**. An enterprise shall here be considered in its whole within its external environment as an **unique integrated system** which shall be – as realistically as possible – modeled & simulated by **integrating coherently** many realistic specialized models.

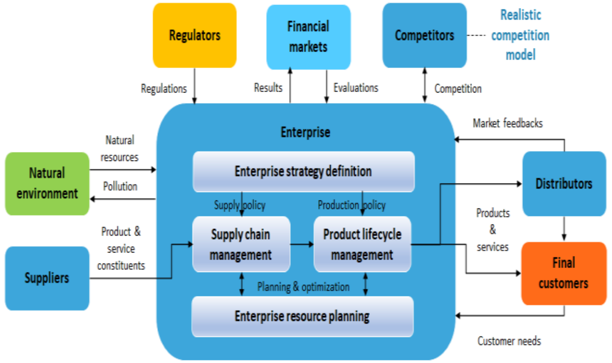
Our technology: the WorldLab systemic intelligence workshop (1/2)



To support our vision, we developed the **WorldLab patented technology** – built on the **proven infrastructure of the AltaRica safety & reliability analysis tool**, developed by Antoine RAUZY during the last 20 years and industrially used in many industrial sectors – which is a **systemic intelligence workshop** that offers enterprise systemic modelling and scenario stochastic simulation & evaluation capabilities.

CESAMES

Our technology: the WorldLab systemic intelligence workshop (2/2)



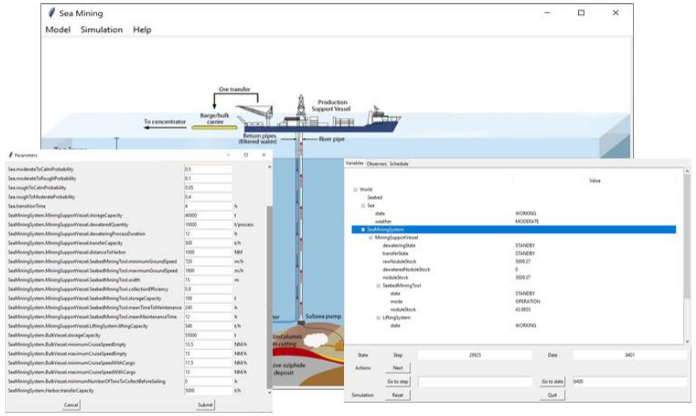
Enterprise unformal model

```
system World
  system Supplier ... end
  system Producer ... end
  system Consumer ... end
end

system World.Supplier
  int rawMaterial(init = 0);
end

system World.Producer
  int order(init = 0);
  int rawMaterial(init = 0);
  int product(init = 0);
end

system World.Consumer
  int product(init = 0);
end
```

Sigma

Enterprise Σ model

WorldLab



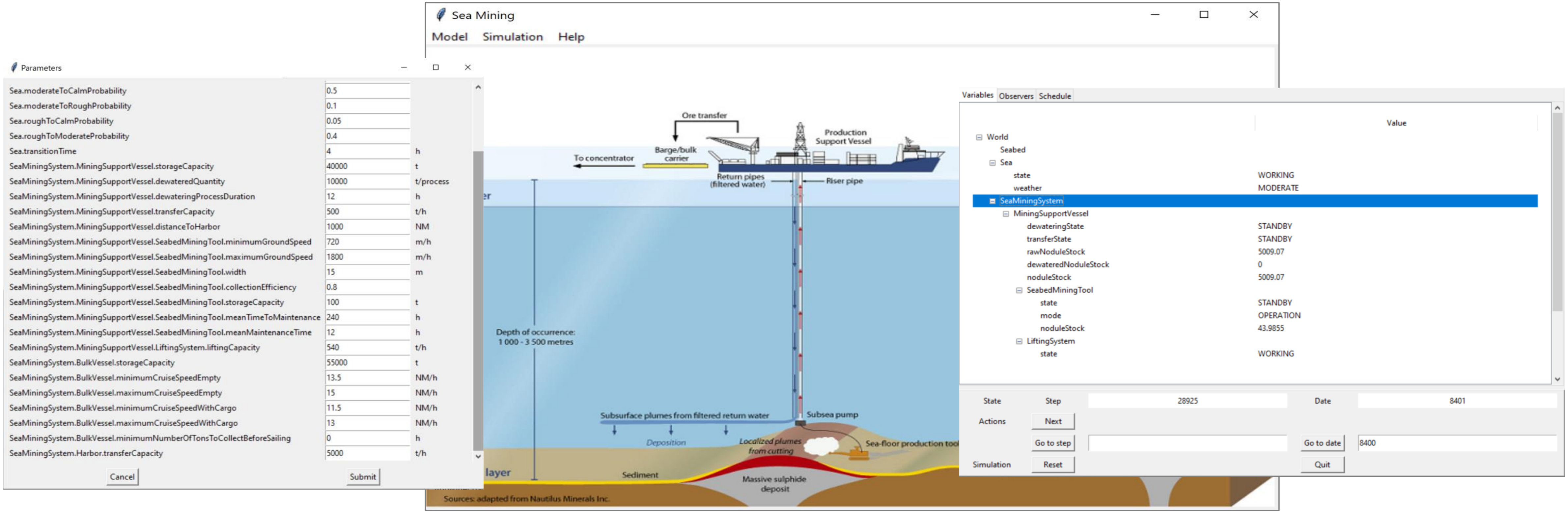
Enterprise systemic digital twin

Principle of the development of an enterprise systemic digital twin with Σ and WorldLab

The **WorldLab technology** especially allows to **produce automatically systemic digital twins** from a **high level specification** designed in our **Σ formal modeling language**. These systemic digital twin shall then accessible in **software-as-a-service mode** or through a local deployment our customer servers, if necessary (for instance for data confidentiality issues).

CESAMES

Examples of uses – Enterprise scale optimization



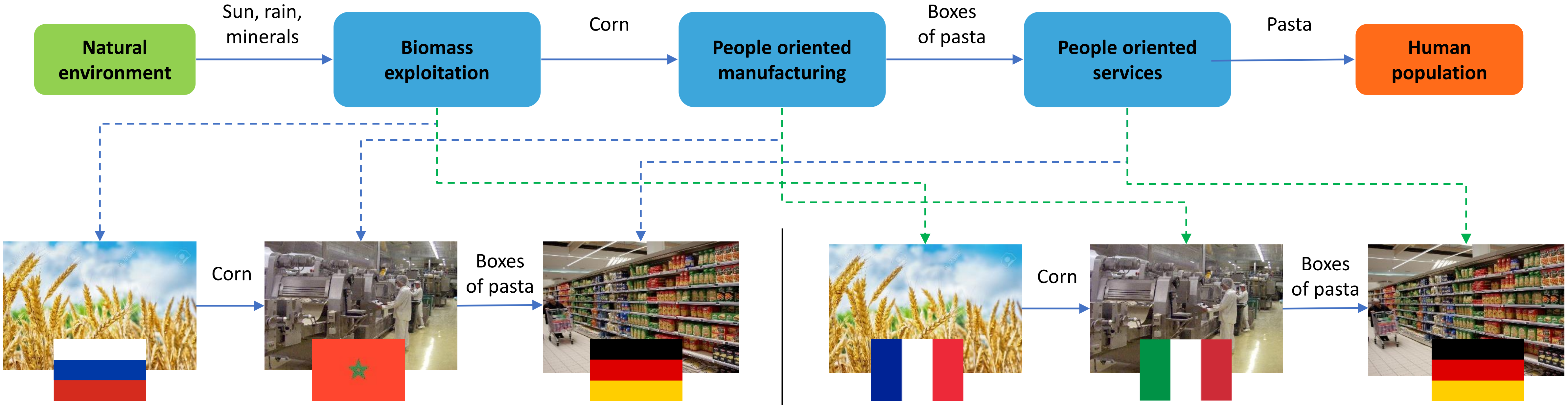
Example of a systemic digital twin for a sub-marine mining exploitation which was constructed with WorldLab systemic intelligence workshop

A proof of concept of the WorldLab technology was already achieved and used to create a **systemic digital twin of a sub-marine mining exploitation in the North sea**, with objective to dimension the mining system in order to maximize the **production rate of minerals**, taking into account the **meteorological conditions** of the sea and the **market price** of the extracted minerals, and **minimizing the investment and the environmental footprint** of the mine.

CESAMES

Examples of uses – Economic sector optimization

Example of a food-delivery value chain reconfiguration within the economic system



Value chain implementation before covid-19 crisis optimized in an open globalized world

(corn is produced in Russia, pasta are manufactured in Morocco and consumed in Germany)

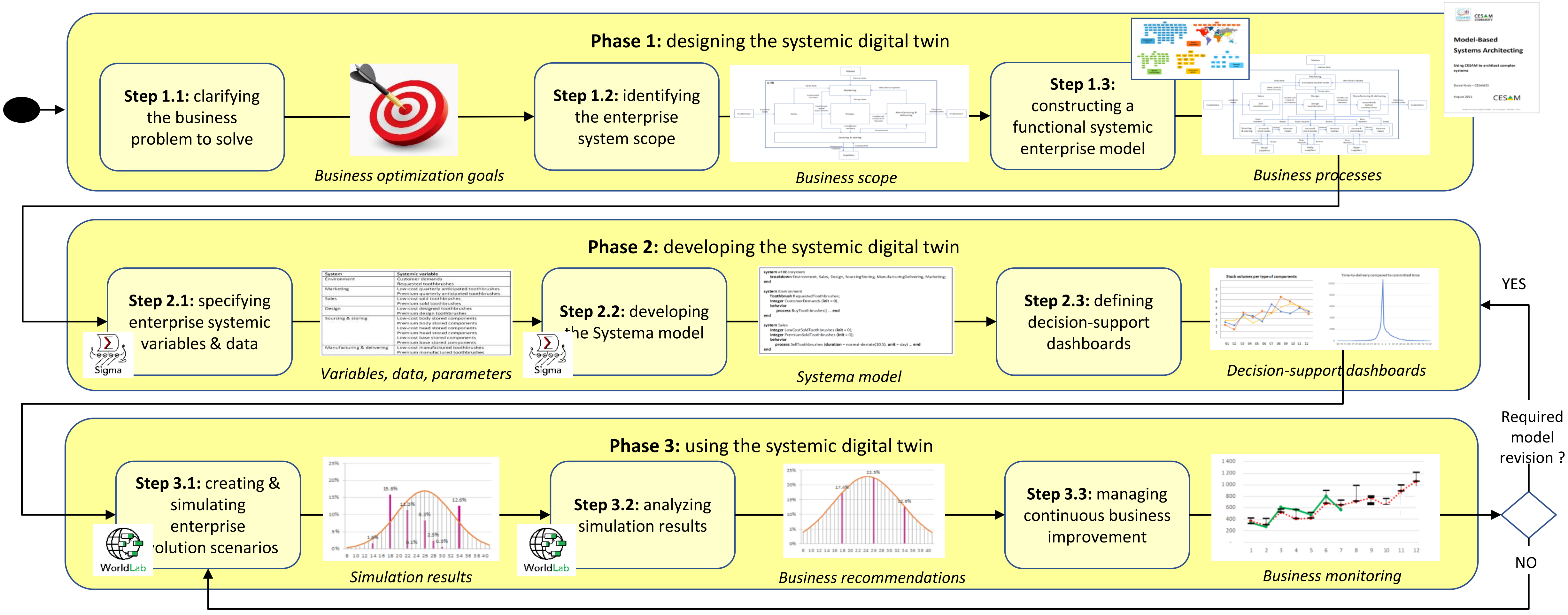
Value chain implementation after covid-19 crisis in a more local-oriented world

(corn is produced in France, pasta are manufactured in Italy and consumed in Germany)

The WorldLab technology can also be used to address more global problems such as **value chain reconfiguration** within the economy, that is to say how to **optimally change the way** a value chain is concretely implemented while **functionally preserving it** and taking into account the **environment uncertainties.**

CESAMES

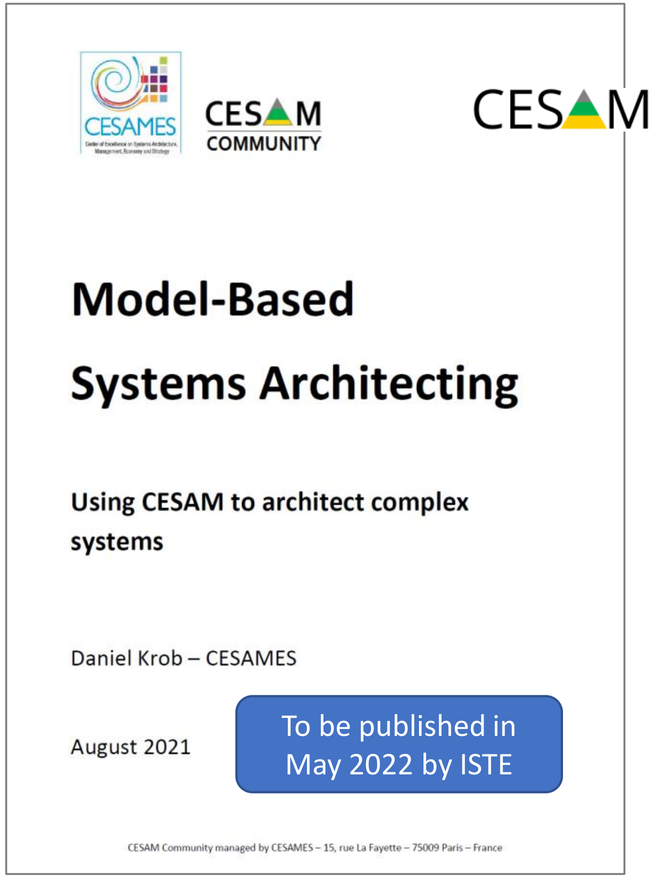
A key asset: a standard methodology for developing a systemic digital twin



How to develop a systemic digital twin?

Our **systemic digital twin development approach** is based on a **standard methodology** which is fully documented.

Our innovation pillars – CESAM, Σ and WorldLab


CESAMES

CESAM COMMUNITY

CESAM

Model-Based

Systems Architecting

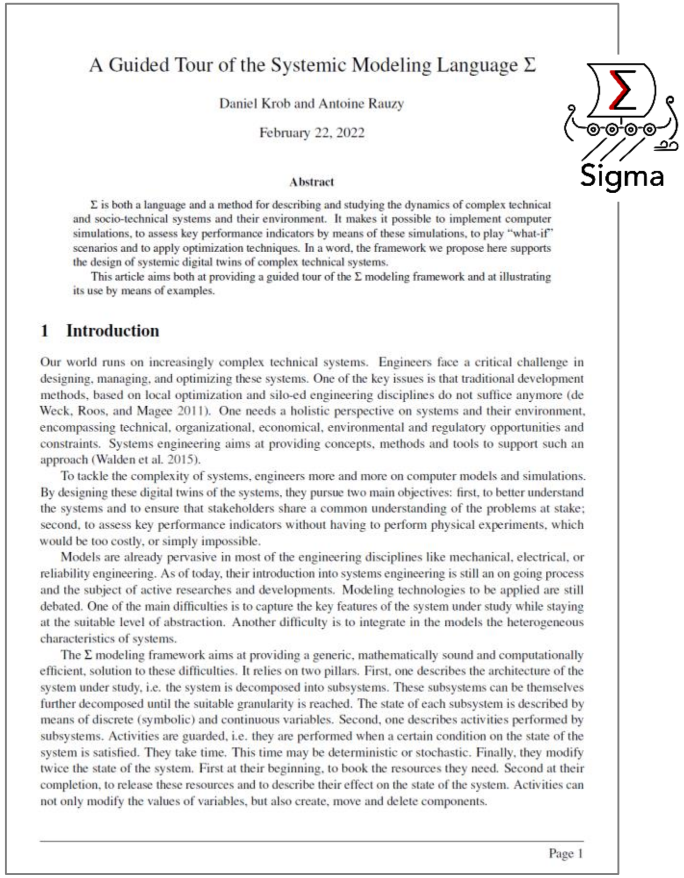
Using CESAM to architect complex systems

Daniel Krob – CESAMES

August 2021

To be published in May 2022 by ISTE

CESAM Community managed by CESAMES – 15, rue La Fayette – 75009 Paris – France


A Guided Tour of the Systemic Modeling Language Σ

Daniel Krob and Antoine Rauzy

February 22, 2022

Sigma

Abstract

Σ is both a language and a method for describing and studying the dynamics of complex technical and socio-technical systems and their environment. It makes it possible to implement computer simulations, to assess key performance indicators by means of these simulations, to play "what-if" scenarios and to apply optimization techniques. In a word, the framework we propose here supports the design of systemic digital twins of complex technical systems.

This article aims both at providing a guided tour of the Σ modeling framework and at illustrating its use by means of examples.

1 Introduction

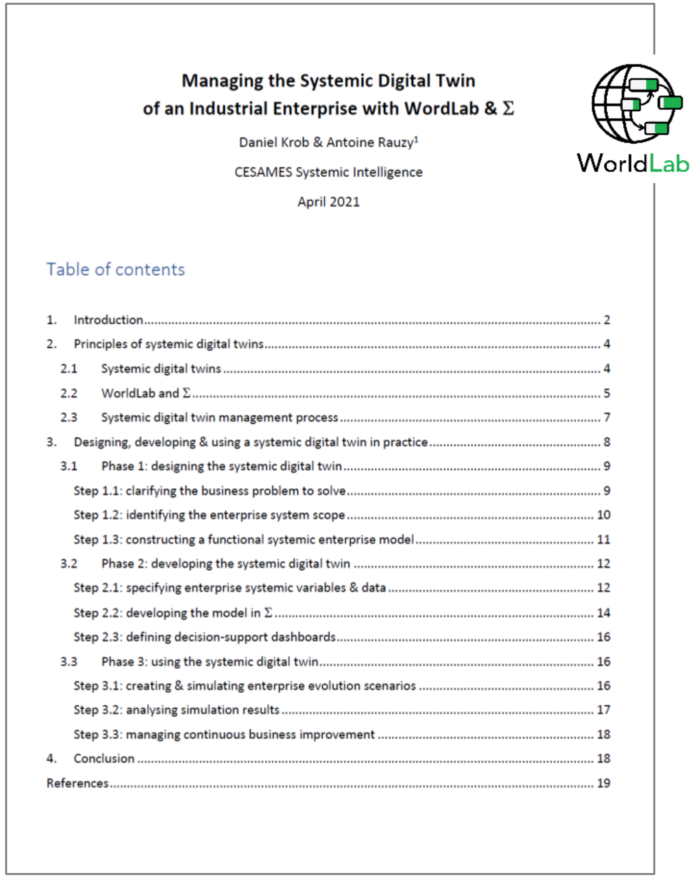
Our world runs on increasingly complex technical systems. Engineers face a critical challenge in designing, managing, and optimizing these systems. One of the key issues is that traditional development methods, based on local optimization and silo-ed engineering disciplines do not suffice anymore (de Weck, Roos, and Magee 2011). One needs a holistic perspective on systems and their environment, encompassing technical, organizational, economical, environmental and regulatory opportunities and constraints. Systems engineering aims at providing concepts, methods and tools to support such an approach (Walden et al. 2015).

To tackle the complexity of systems, engineers more and more on computer models and simulations. By designing these digital twins of the systems, they pursue two main objectives: first, to better understand the systems and to ensure that stakeholders share a common understanding of the problems at stake; second, to assess key performance indicators without having to perform physical experiments, which would be too costly, or simply impossible.

Models are already pervasive in most of the engineering disciplines like mechanical, electrical, or reliability engineering. As of today, their introduction into systems engineering is still an on going process and the subject of active researches and developments. Modeling technologies to be applied are still debated. One of the main difficulties is to capture the key features of the system under study while staying at the suitable level of abstraction. Another difficulty is to integrate in the models the heterogeneous characteristics of systems.

The Σ modeling framework aims at providing a generic, mathematically sound and computationally efficient, solution to these difficulties. It relies on two pillars. First, one describes the architecture of the system under study, i.e. the system is decomposed into subsystems. These subsystems can be themselves further decomposed until the suitable granularity is reached. The state of each subsystem is described by means of discrete (symbolic) and continuous variables. Second, one describes activities performed by subsystems. Activities are guarded, i.e. they are performed when a certain condition on the state of the system is satisfied. They take time. This time may be deterministic or stochastic. Finally, they modify twice the state of the system. First at their beginning, to book the resources they need. Second at their completion, to release these resources and to describe their effect on the state of the system. Activities can not only modify the values of variables, but also create, move and delete components.

Page 1


Managing the Systemic Digital Twin of an Industrial Enterprise with WordLab & Σ

Daniel Krob & Antoine Rauzy[1]

CESAMES Systemic Intelligence

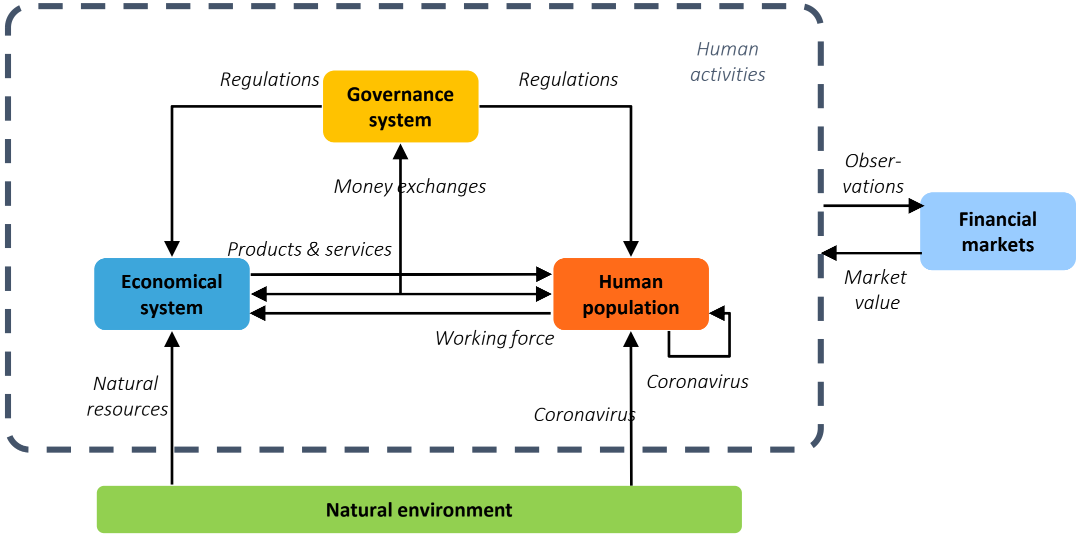
April 2021

WorldLab

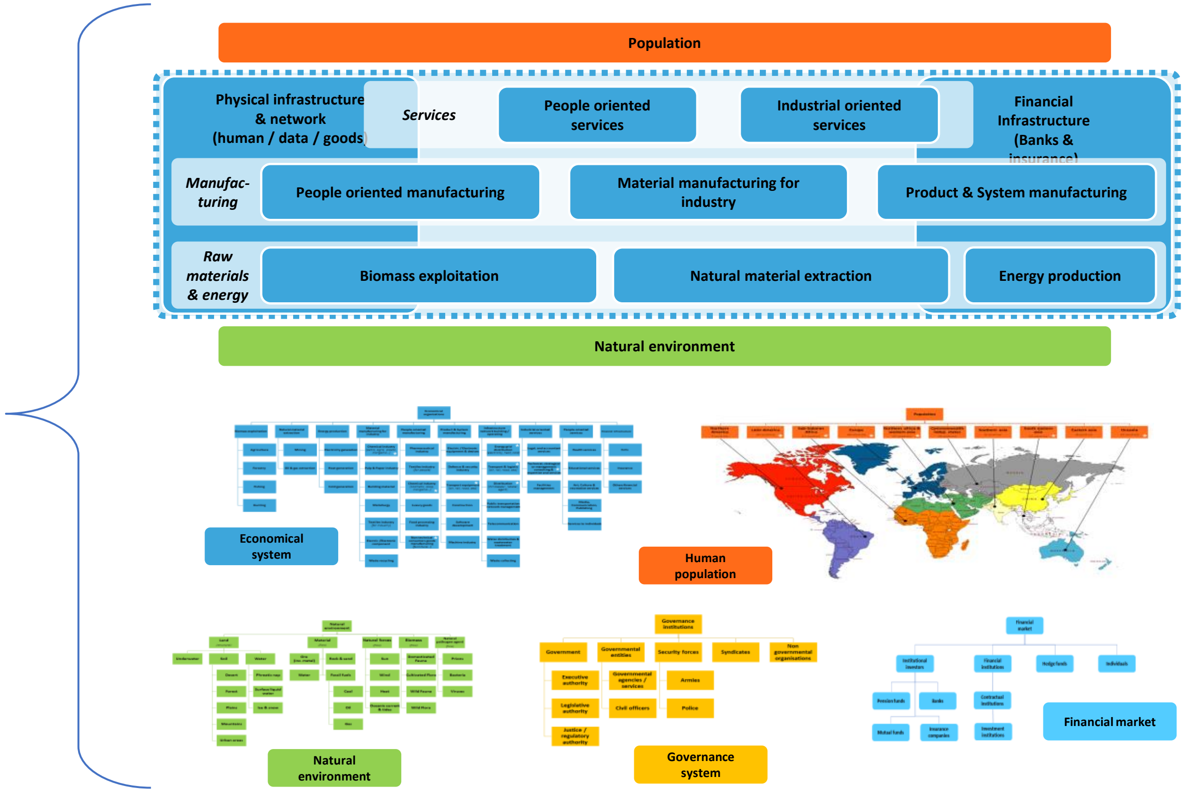
Table of contents

Our **systemic digital twin development approach** rely on many innovative pillars such as 1) the **CESAM system architecting method** used in the **design phase**, 2) the new **systemic modeling / simulation formal language Σ** used in the **beginning of the development phase**, 3) the **WorldLab platform** that supports the **end of the development phase** and the **use phase**.

Our innovation pillars – CESAM world model



Source: de Weck O., Krob D., Li L., Lui P.C., Rauzy A;, Zhang X., *Handling the COVID-19 crisis: Toward an agile model-based systems approach*, Systems Engineering, 23 (5), 656-670, Sept. 2020 – **Best paper 2020 of the Systems Engineering journal**



Our **systemic digital twin development approach** also rely on an **innovative world model** which is used to position in a standard way each enterprise within its environment. The world is here broken down into 5 mains systems: 1) the **natural environment** formed of all natural resources that are involved in human activities, 2) the **human population** who was stressed by the coronavirus, 3) the **economical system** formed of all economical entities in the world, 4) the **governance system** formed of all state political & regulatory entities on Earth, 5) the **financial markets** that are observing the human activities and providing their market values.

Key features of our technology

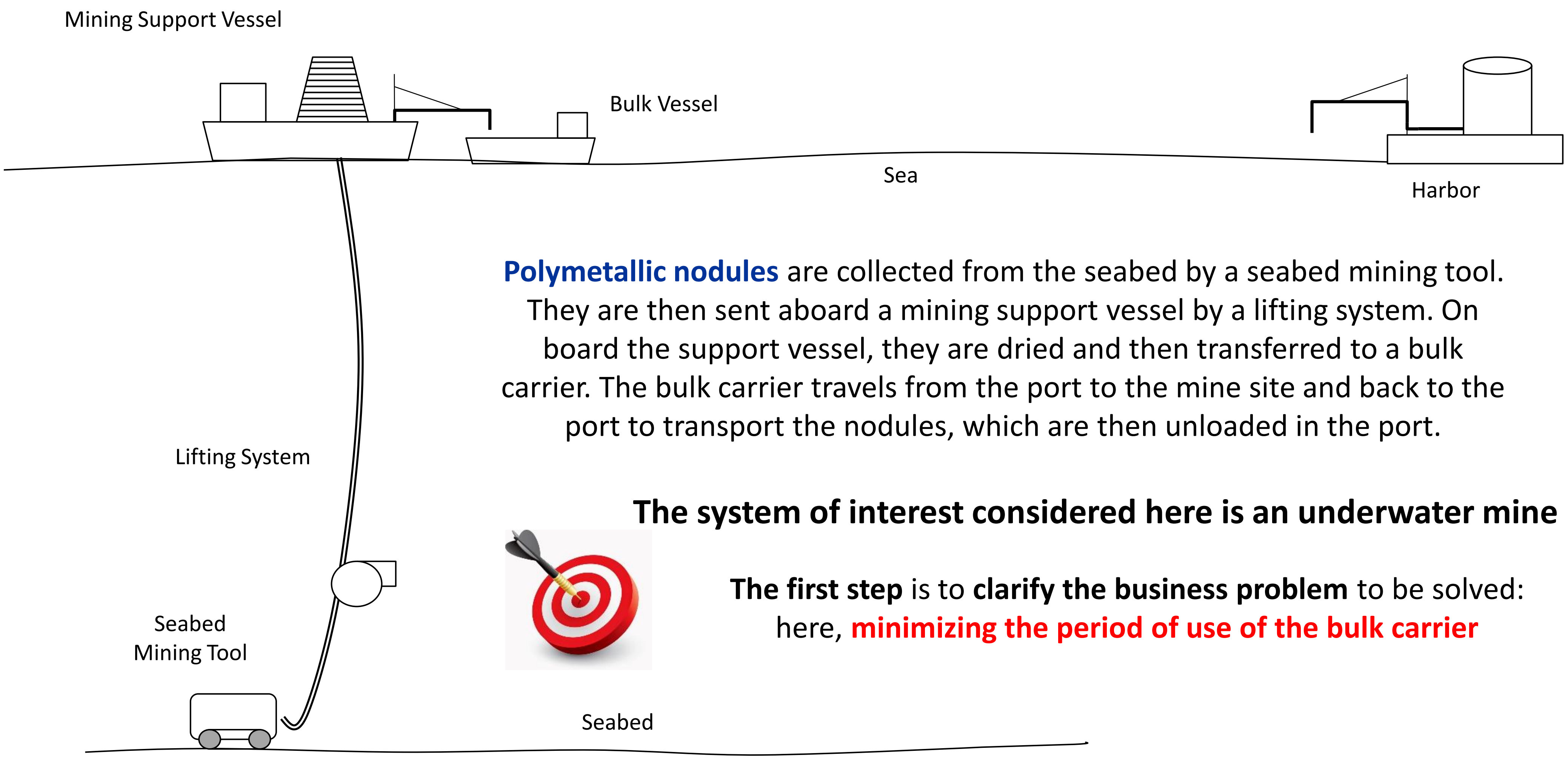
- A systemic digital twin integrates **various heterogeneous features** in a **single unique systemic model**. One can therefore express in the same model both technical functions, maintenance policies, societal behaviors, financial market evolutions, regulatory strategies or meteorologic conditions and analyze a given industrial system from these various perspectives.
- A systemic digital twin is specified in the **generic object-oriented modeling language Σ** which is quite simple to use to any person with an algorithmic-design background. This modeling language especially allows to express **concurrent timed transformation activities** of an industrial system, which is currently not offered by the existing similar languages.
- **Operational data** are managed through **abstraction mechanisms** that allow to avoid dealing with details when they are not mandatory, while focusing on the most important trends captured by the data. This choice also allows to gain into execution performance when one needs to deal with complex simulations.
- A given systemic digital twin is **automatically generated** from its Σ specification due to its formal nature which supports simulation due to its underlying formal semantics mathematical framework. This flexible mechanism allows to **quickly develop**, typically within a few weeks, a first version of a systemic digital twin when the modeling phase is finished.
- The WorldLab platform proposes dedicated features for **evaluating & prioritizing evolution scenarios** which allow to manage **multi-criteria optimization** with respect to a given industrial system.
- **Dashboards and alerting mechanisms** allow to respectively support operational & strategic decisions and identify the deviations of a given industrial system with respect to its normal trajectory depending on its environment behavior.
- Last, but not least, a **strong methodological environment**, covering design & development techniques, environment / world modeling and systemic data modeling, is offered to the WorldLab users.

CESAMES

Agenda

CESAMES

An application case: underwater mining



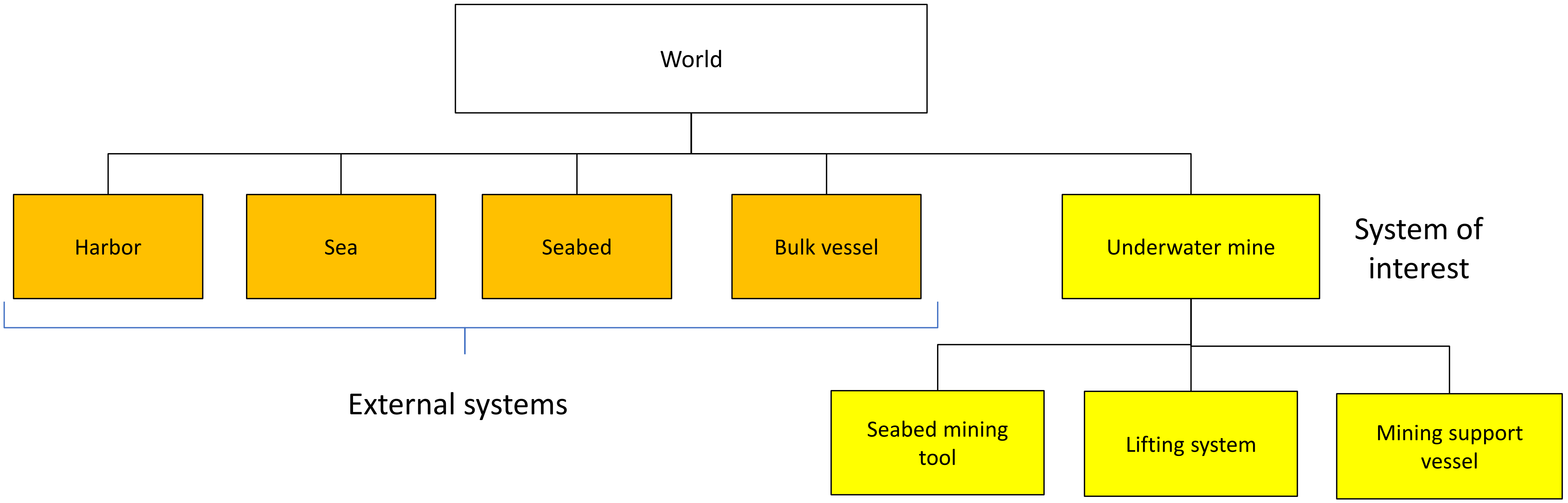
Polymetallic nodules are collected from the seabed by a seabed mining tool. They are then sent aboard a mining support vessel by a lifting system. On board the support vessel, they are dried and then transferred to a bulk carrier. The bulk carrier travels from the port to the mine site and back to the port to transport the nodules, which are then unloaded in the port.

The system of interest considered here is an underwater mine

The first step is to **clarify the business problem** to be solved: here, **minimizing the period of use of the bulk carrier**

An application case of WorldLab platform: an underwater mine

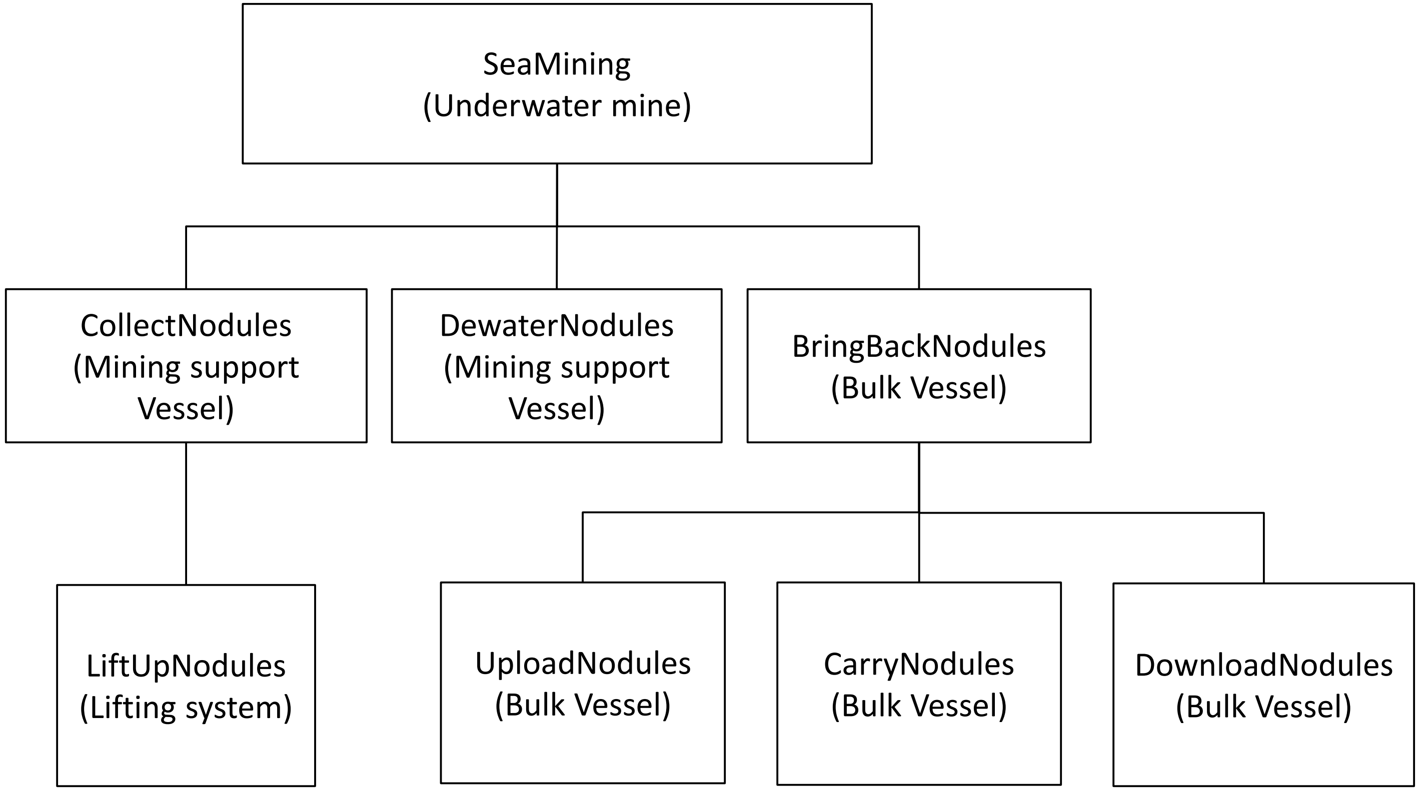
An application case: underwater mining
Phase 1: design the systemic digital twin (1/2)



System breakdown of the environment of the system of interest

An application case: underwater mining

Phase 1: design the systemic digital twin (2/2)

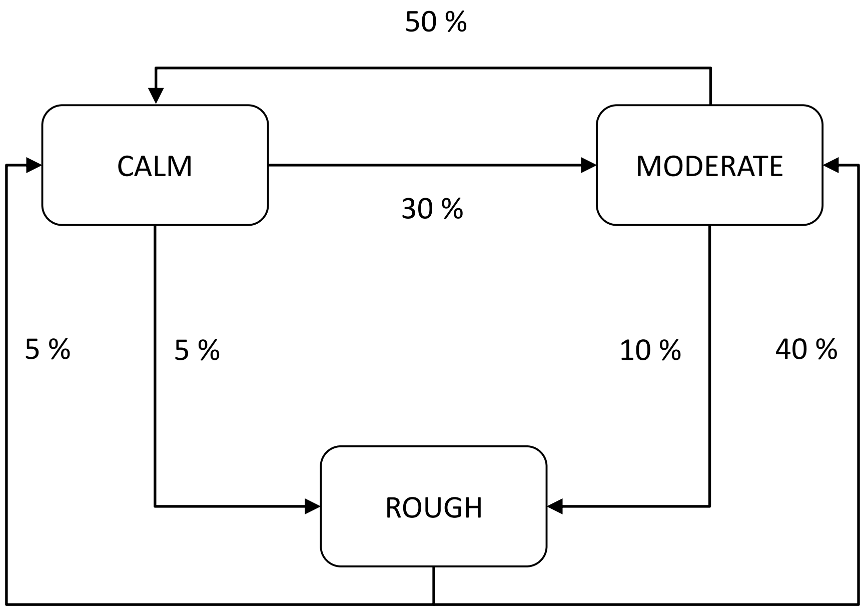


Simplified functional breakdown of the perimeter of interest

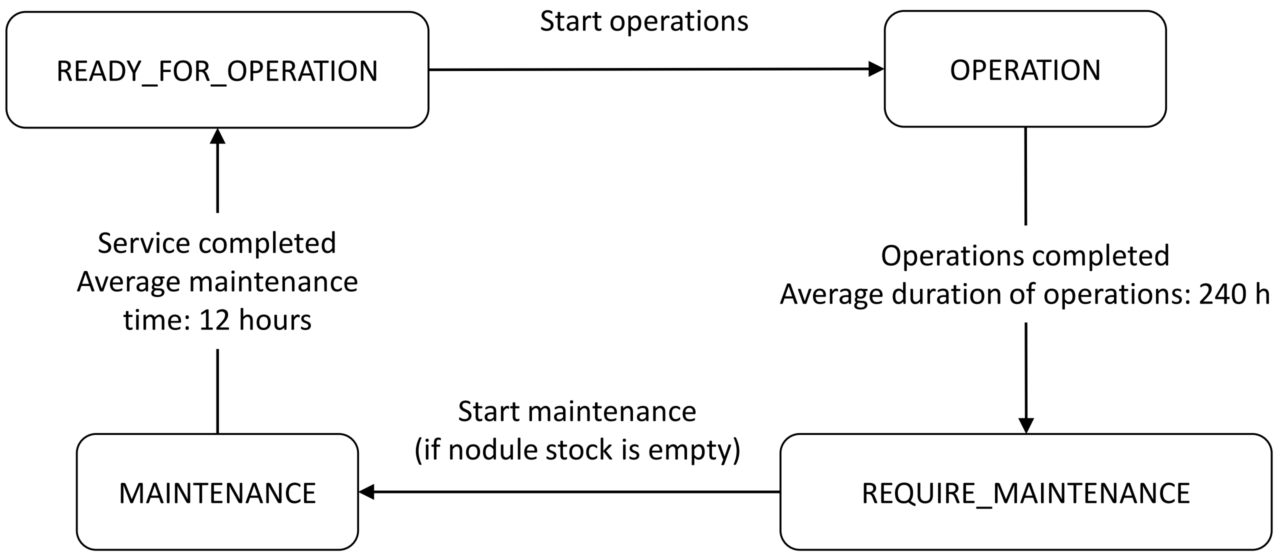
- The sea changes the weather
- The seabed mining tool is in operation or maintenance
- The seabed mining tool collects the raw nodules on the seabed
- The lifting system brings the raw nodules back to the mining support vessel
- The mining support vessel dewaters the raw nodules and transfers the dry nodules to the bulk carrier
- The bulk carrier makes a round trip between the port and the operating site
- Port unloads dry nodules from bulk carrier

Rules of operations of the perimeter of interest

An application case: underwater mining
Phase 2: develop the systemic digital twin



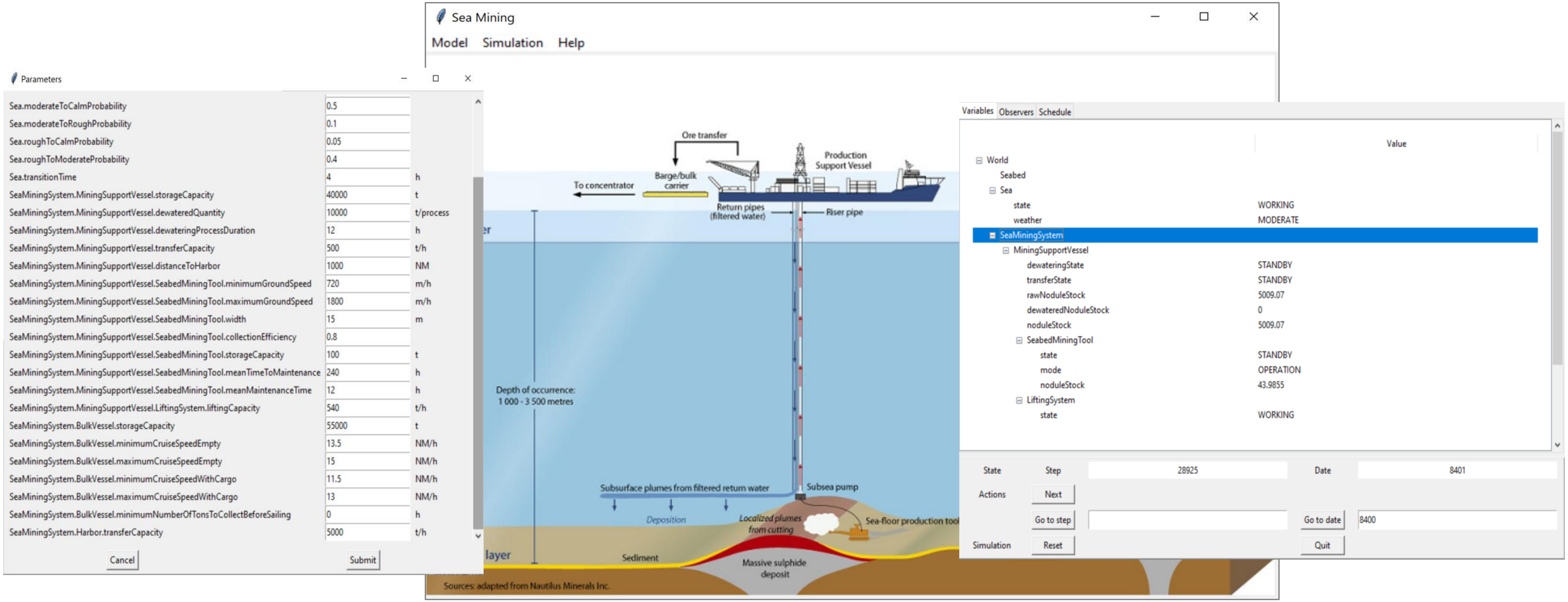
Modeling of the state of the sea on site over a time step of 4 hours (based on historical data)



Modeling the operation of the seabed mining tool

An application case: underwater mining

Phase 3: using the systemic digital twin



Example of a systemic digital twin for a sub-marine mining exploitation which was constructed with WorldLab systemic intelligence workshop

Agenda

1. Systemic Intelligence Group
2. Why systemic digital twins?
3. What is a systemic digital twin?
4. An illustrating example: a submarine mine
5. **Questions & answers**

Contact

Daniel KROB
Chairman
daniel.krob@systemic-intelligence.net
+ 33 (0)6 60 42 34 49

Systemic Intelligence Group
Private Limited Company with share capital of 20,000 €
15, rue La Fayette – 75009 Paris – France
SIRET : 805 084 670 00027 – Member of CESAMES group

WorldLab

Questions / réponses

Analyse des risques induits par le changement climatique sur l'outil productif

Apport d'une approche système

Sébastien Berthier

Directeur Recherche et Développement

Syscience

Analyse des risques induits par le changement climatique sur l'outil productif : Apport d'une approche système

Dr. Sébastien BERTHIER, Dr. Pascal KRAPF, Celia OUKIL

Presenting Author, Dr. Sébastien BERTHIER

Affiliation, SYSCIENCE

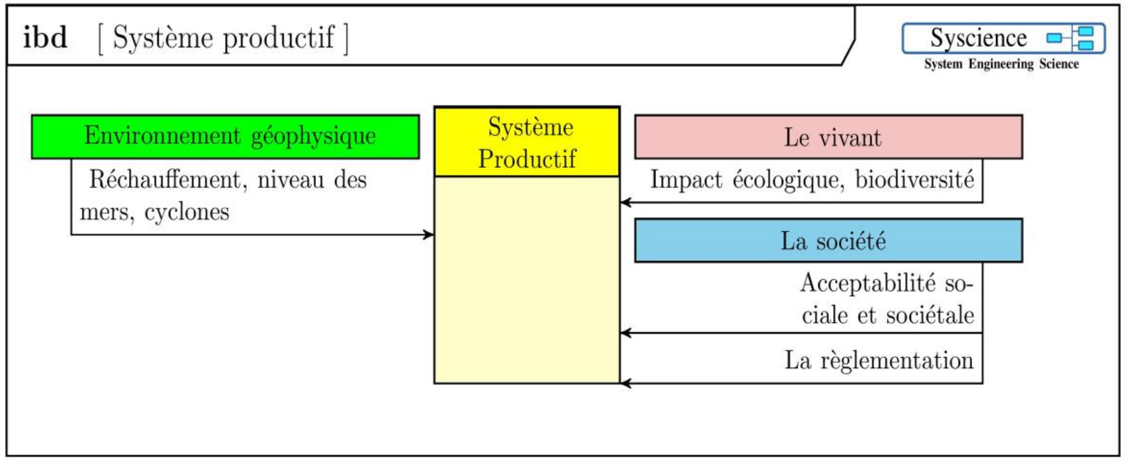
Sebastien.berthier@syscience.fr

Le risque climatique

- Un quasi-consensus scientifique existe quant à la réalité du **Changement Climatique** (C.C.) .
- **Conséquences** prévues par le **GIEC** : ↑Températures, ↑niveau des mers, augmentation des évènements de sécheresses, de précipitations et de cyclones tropicaux violents, …
- … entrainant un renforcement des **risques existants sur les personnes et les biens**, et donc, sur les **installations industrielles**.
- Les **développement futurs** doivent prendre en considération ces changements.
- Les **conditions d'utilisation** des systèmes **industriels existant** seront modifiées par rapport à celles qui ont été supposées lors de leur conception (cf.. Plan Delta).
- Nous devons évaluer et améliorer la **résilience** des Systèmes industriels face au **risque climatique**.
- Guider l'écriture des **politiques de gouvernance** facilitant la prise de décision.


Plan Delta (Oosterscheldekering, Pays-Bas)

Montée du niveau des mers /1900 :
30 cm en 2050, 1.3 m en 2100, 4 m en 2200
1/3 du territoire sous le niveau des mers
… qui contient 2/3 de l'industrie



L'écosystème d'un système productif

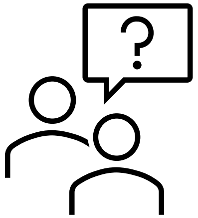
Objectif de l’étude

- Montrer la possibilité d’une estimation des risques encourus par le **tissu industriel, du fait du C.C.**, grâce à une étude prospective de faisabilité
- **<u>Précaution d’usage :</u>** Nous ne cherchons pas à faire une étude quantifiée et aboutie sur l’incertitude climatique. Les données que nous prendrons en compte sont les sorties des mesures et modèles de la communauté scientifique. Nous essayons seulement d’entrevoir/traduire leur effet en termes d’impact sur l’outil industriel

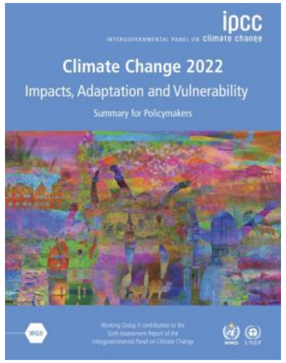
Formalisation du risque climatique

- On note par ECR un Evènement Climatique Redouté
- La criticité des dommages entrainés par un **ECR** sur un **système** peut être écrit de la manière suivante :

$$\text{Criticité du risque}(\text{Syst}_i) = \text{Prob\_survenance}(\text{ECR}) \,.\, \text{Exposition}(\text{Syst\_i/ECR}) \,.\, \text{CoûtduDommage}(\text{ER/Syst})$$



Rapport GIEC/IPCC



- **Accidentologies des NaTech : ARIA**
  Compilation des scénarios d'incident industriels passés, et en particulier ceux impliquant des NaTech (https://www.aria.developpement-durable.gouv.fr)

  ARIA

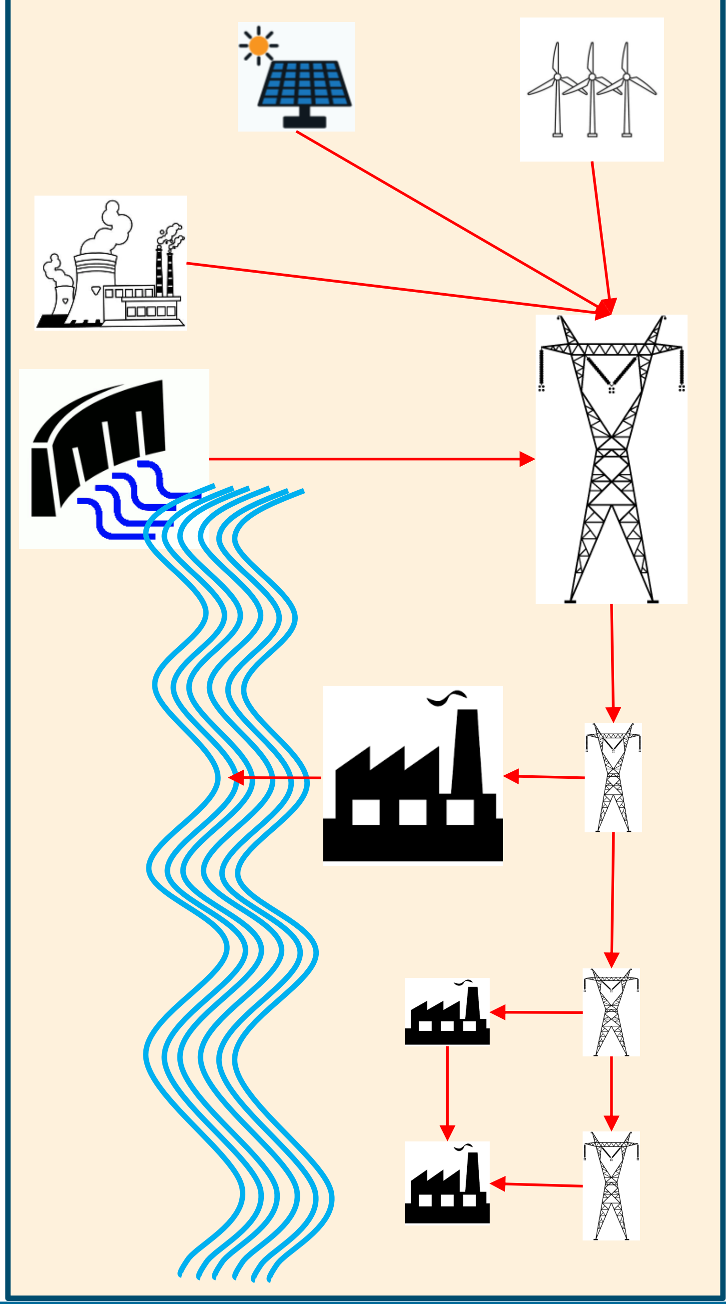
- **Modélisation de l'écosystème industriel**

Une approche systémique

- Une **installation industrielle** peut être décrite, dans une approche systématique comme un **système, ou plus exactement, un système de systèmes** permettant de remplir un ou plusieurs objectifs définis.
- Ce **système de systèmes** est caractérisé par une complexité plus ou moins importante :
- **Interne :** Il est le savant résultat architectural de l’intégration d’un ensemble plus ou moins nombreux d’éléments (Matériels, Logiciels, Processus, Personnes, Informations, Techniques, Equipements, Services, …), ces derniers comportant leur propre part de complexités.
- **Externe :** Ce système n’est pas isolé : il est en relation avec son environnement. Cet environnement peut être constitué d’un tissus plus ou moins complexe de systèmes, avec lequel notre système considéré échange au travers de flux d’énergie, d’information, etc.

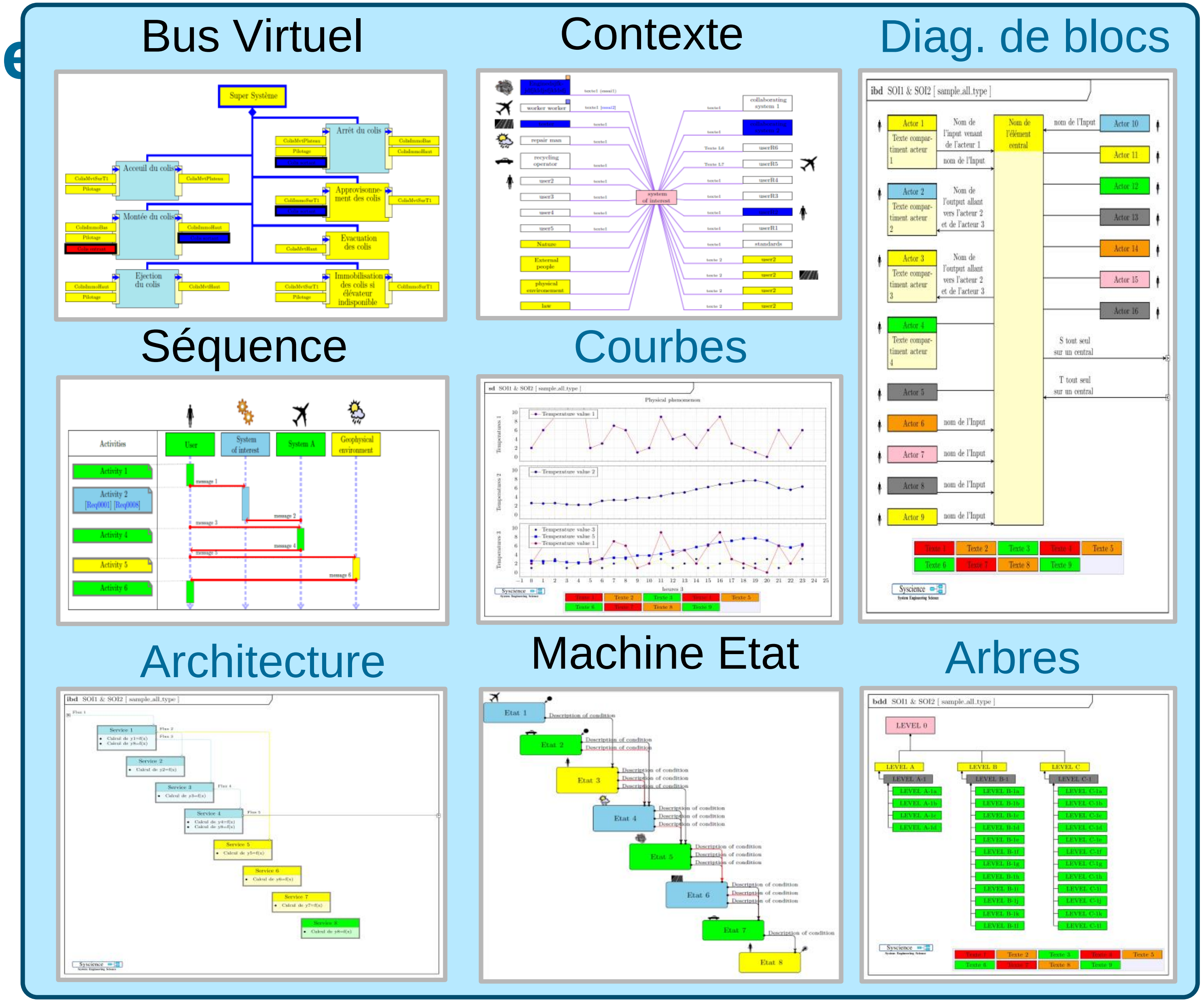
Analyse de la complexité

- Un **écosystème** est le rassemblement de plusieurs systèmes en **interactions (système de systèmes)**.
- Nous cherchons à connaitre les effets d'une perturbation donnée sur cet écosystème.
- Les sources de complexité peuvent être de plusieurs sortes :
- Des **flux interactions :** qui peuvent être **nombreux**, et de **natures différentes** (Température, Electricité, Information, etc.). Ces flux peuvent être **unidirectionnels**, **bidirectionnels,** voire montrer des **couplages**.
- Des **Systèmes** : qui peuvent être rapidement **nombreux**, montrer une certaine diversité.
- Des **comportements émergent** peuvent naître de par l'association de systèmes différents.
- Des **acteurs métiers différents** (vision **globale/locale**, **process** et **langages**).
- Un outil dédié, l'**Atelier Syscience** a été développé afin d'appréhender cette complexité.



Outil : L'Atelier Syscience

- Cet atelier n'est pas dédié aux études de sécurité mais vise à **modéliser de façon collaborative les processus de l'Ingénierie Système**.
- Il permet de représenter les principaux **diagrammes** support de l'ingénierie système.
- … et de générer automatiquement certaines **exigences** à partir de ces diagrammes !
- Points forts de cet outil :
- Une grande simplicité,
- Un dictionnaire partagé (ontologie) facilitant les pratiques collaboratives (mutualisation, capitalisation),
- Fusions intelligentes d'informations.



Syscience
System Engineering Science

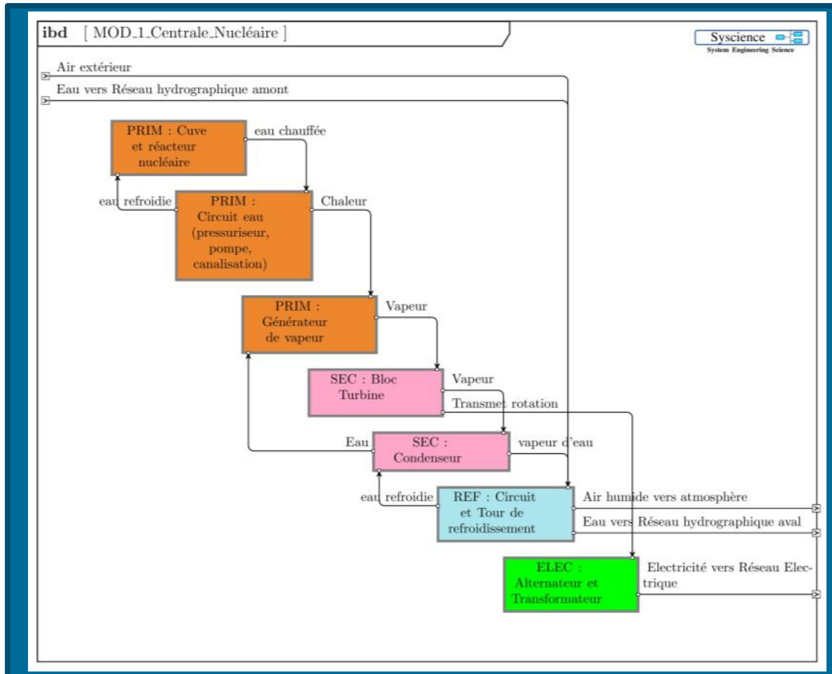
Méthodologie

- La démarche proposée s'inspire de la **méthode Syscience** : elle permet l'identification des risques associés à l'introduction d'un nouveau produit, d'une nouvelle fonctionnalité ou d'une modification de son environnement [Krapf et Loise, 2016]
- Une **approche globale** : Elle intègre les activités de sûreté de fonctionnement et d'analyse de sécurité à l'Ingénierie Système (I.S.).
- Nos **études à lambda mu**:
  - les risques d'un **véhicule connecté** [Krapf, Rakotosolofo et Berthier, 2018]
  - Le **champ d'éoliennes off-shore** [Berthier et Krapf, 2020]
  - La **mise à jour des logiciels sur la voiture autonome** [Oukil, Berthier et Krapf, 2022]

8. **Identification des risques et évaluation de l'impact**
7. **Identification des scénarios et simulation**
6. **Caractérisation des états du système géophysique**
5. **Identification des boucles de rétroactions**
4. **Caractérisation des états du système étudié**
3. **Définition du périmètre de l'étude**
2. **Caractérisation des environnements**
1. **Caractérisation du système industriel**

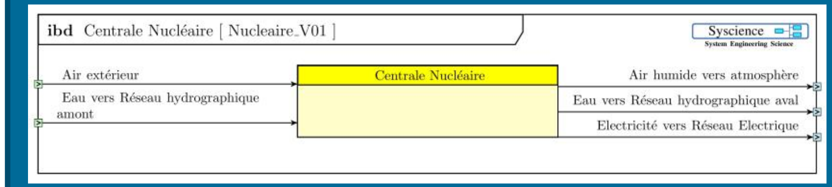
Cas d'étude : Caractérisation du système industriel : la centrale nucléaire

- Afin d'illustrer l'utilisation de notre méthode, nous allons nous intéresser à l'étude d'une **centrale nucléaire**.
- Une vue interne du système doit être donnée : **détaillée** ou en **boite noire**, mais identifiant les entrées et sorties de ce système.
- Une vue externe traduisant **l'environnement de ce système.**



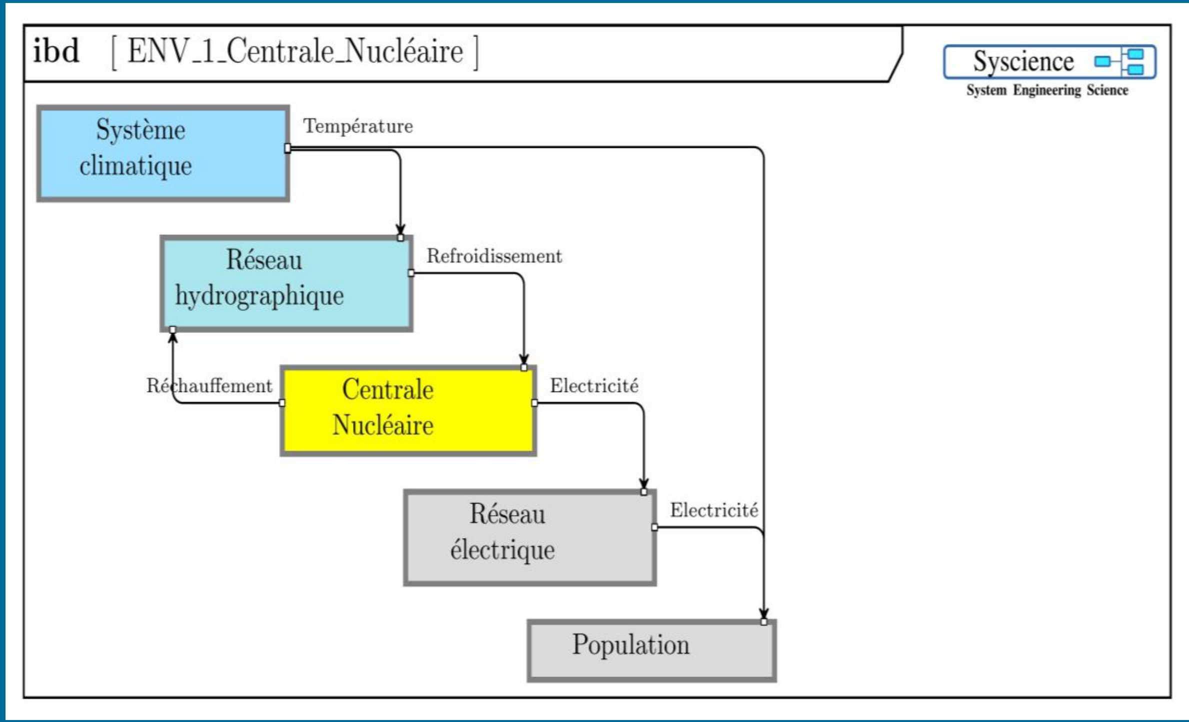
Modèle interne

(Diag. Architecture)



Modèle boite noire

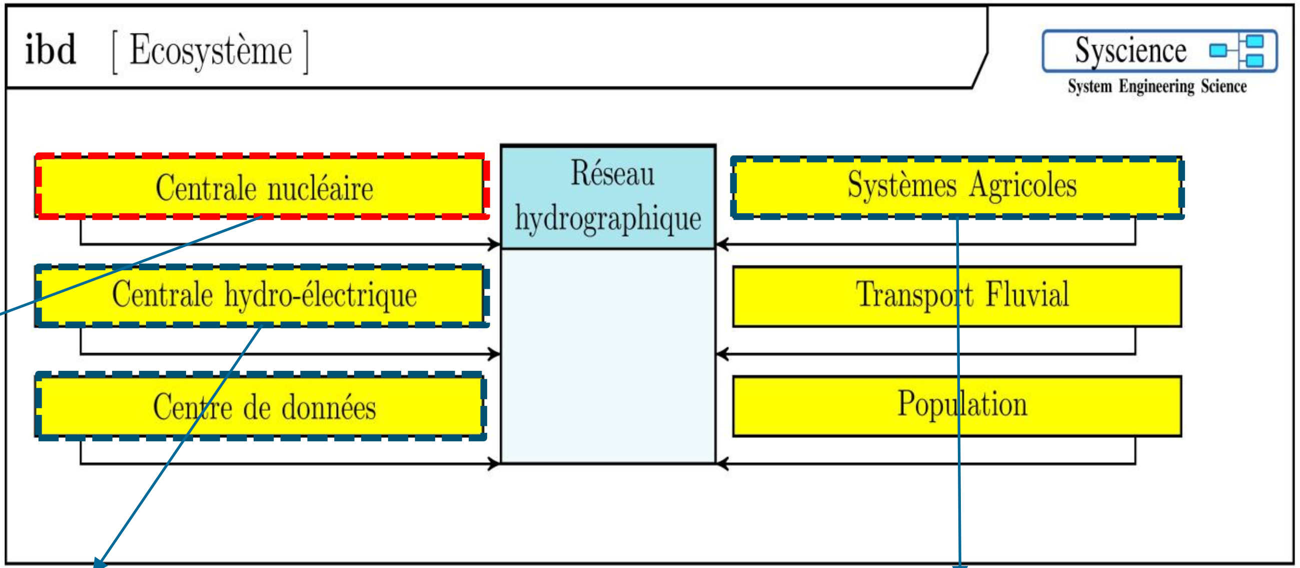
(Diag. SingleBlock)

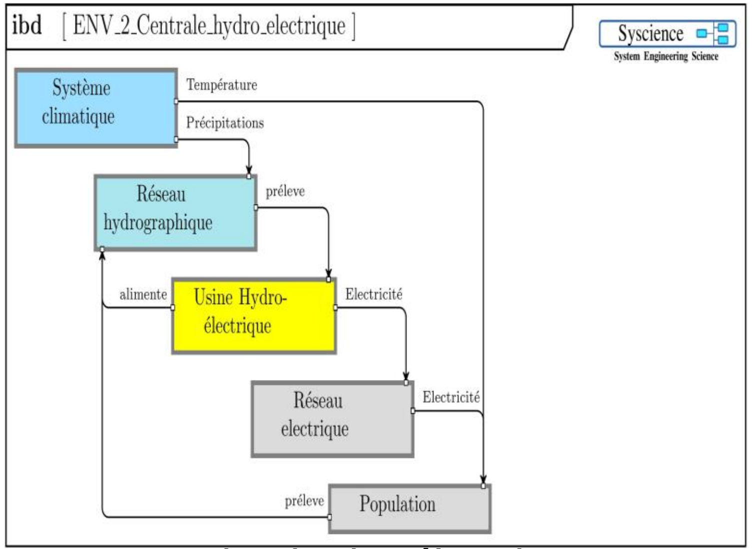


Environnement d'une centrale nucléaire (Diag. Architecture)

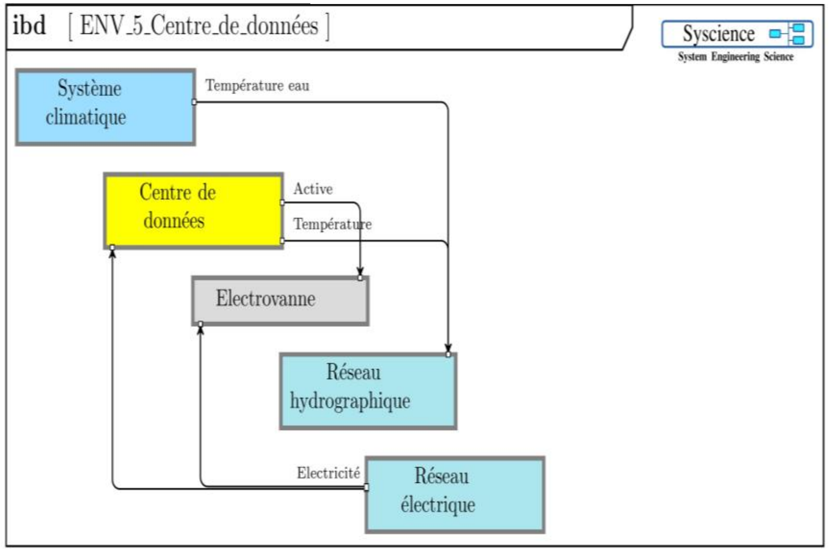
Environnement et périmètre de l’étude

- Nous faisons le choix de décrire un réseau hydrographique, medium au travers duquel des systèmes sont en interaction.
- Nous faisons le choix de prendre en considération différents systèmes

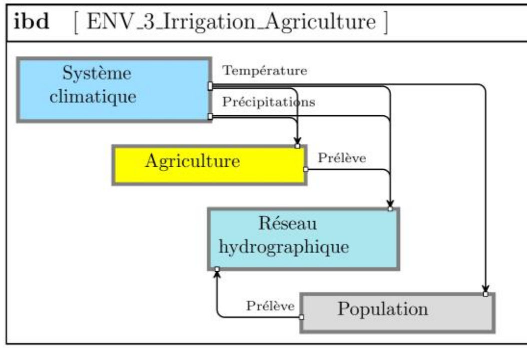




Usine hydro-électrique



Serveur informatique

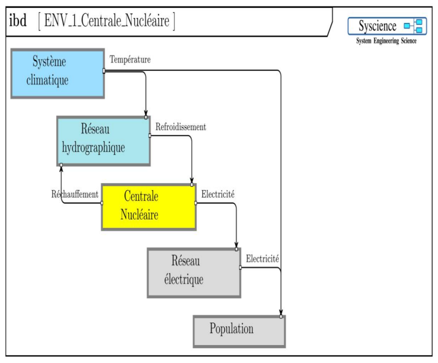


Système agricole

Fusion des environnements

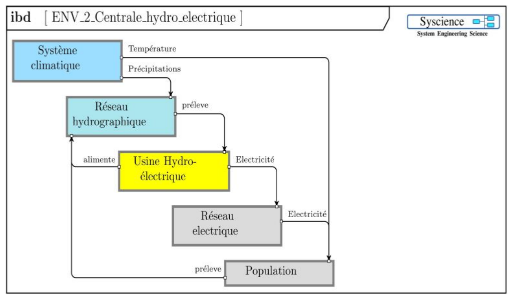
ANALYSE LOCALE

Système considéré

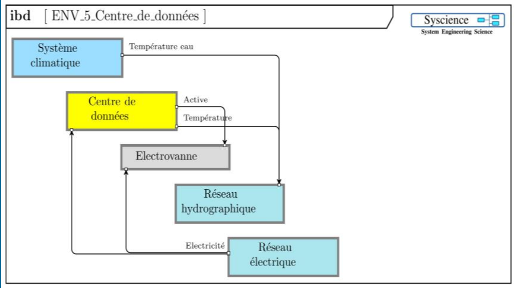


Centrale Nucléaire

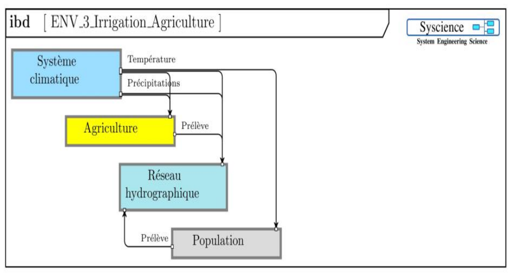
Autres Systèmes



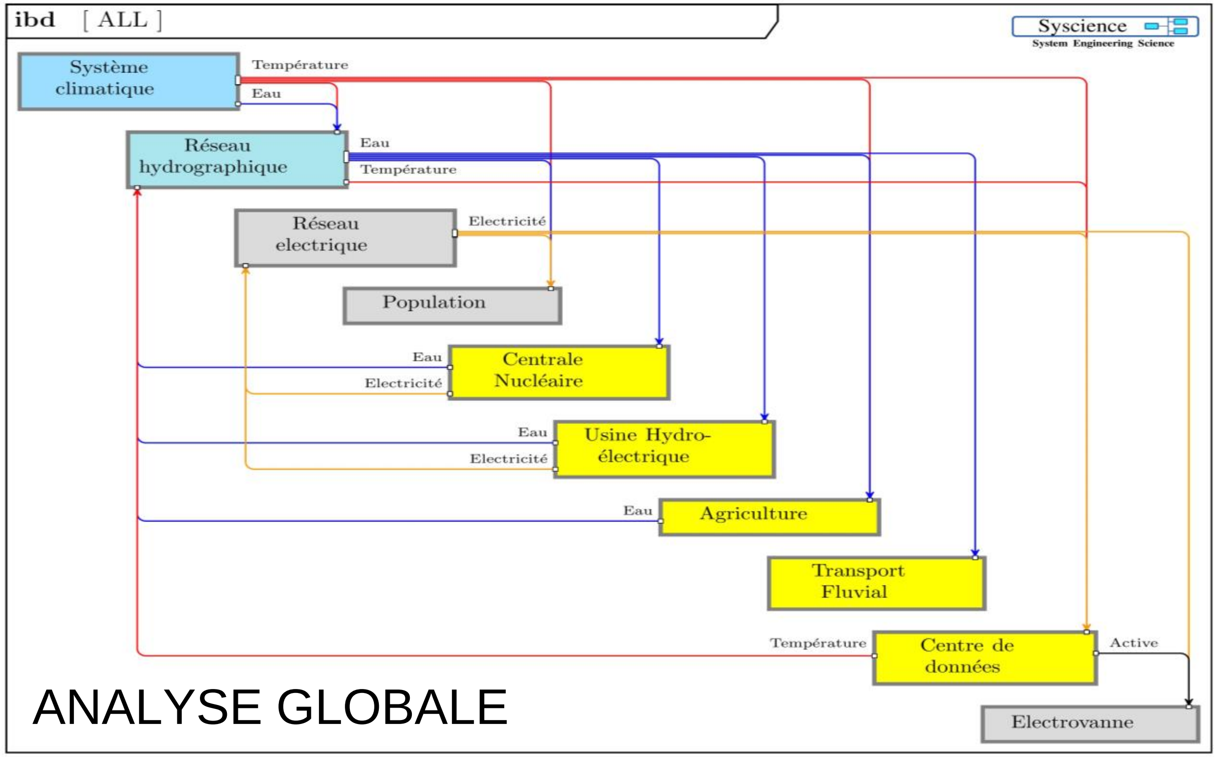
Usine hydro-électrique



Serveur informatique



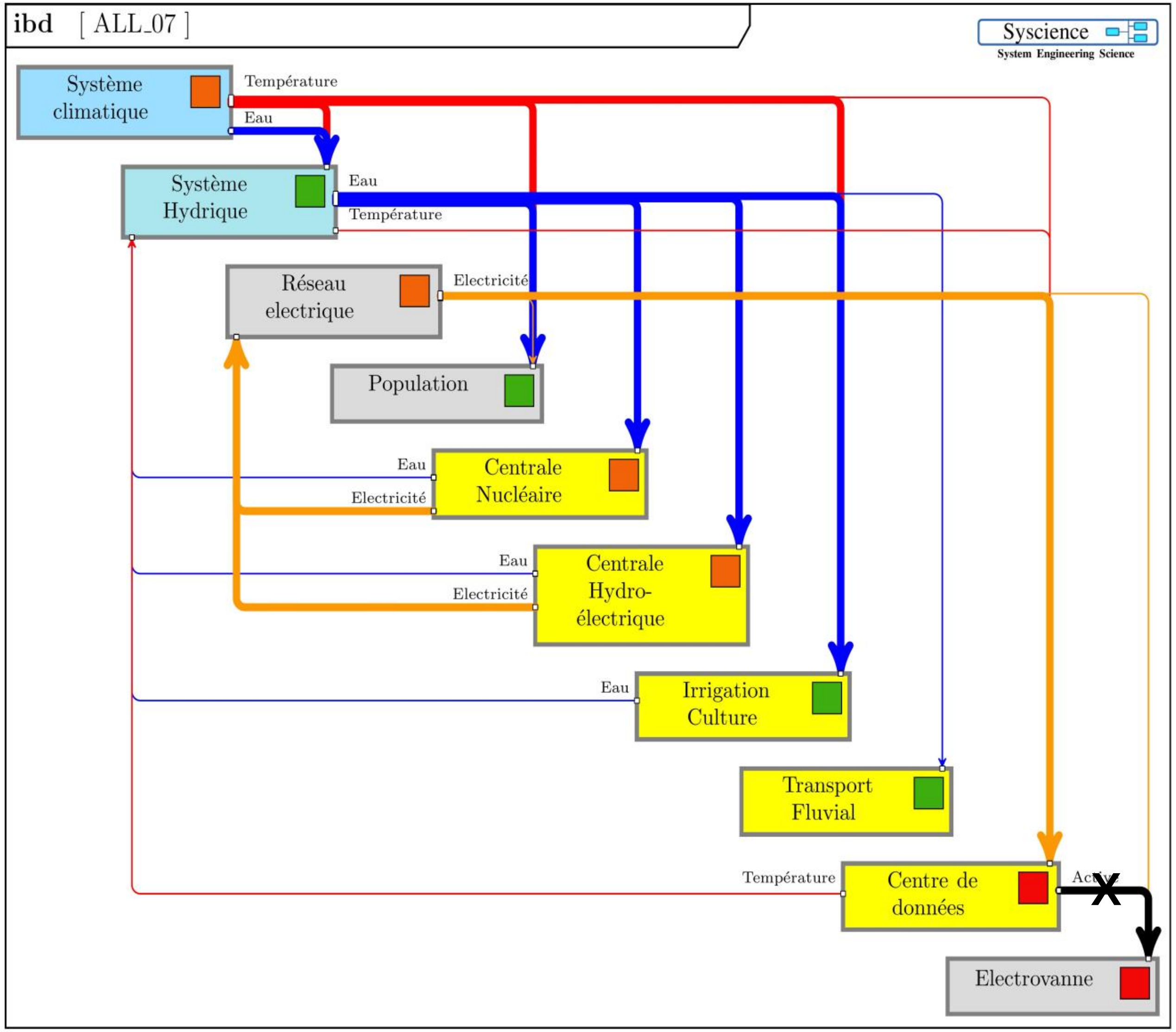
Système agricole

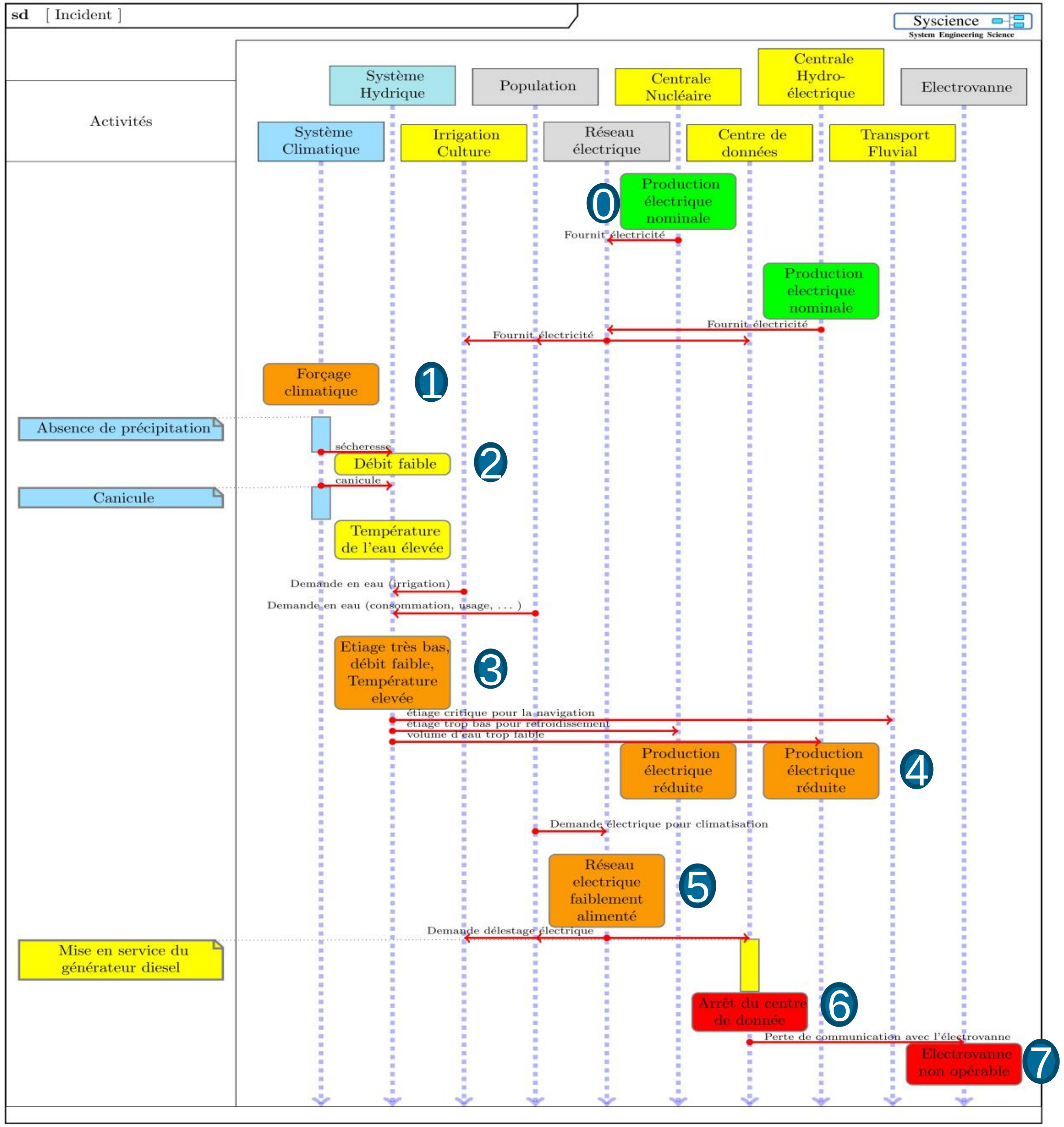


ANALYSE GLOBALE

- On effectue la **fusion automatique** des environnements des systèmes **(vue partielle)** afin d'atteindre une **vision étendue** de l'écosystème.
- Il est possible de **mettre en valeur** l'environnement d'un système spécifique, voire de d'**extraire** au sein de cette vue étendue.
- On identifie des **dépendances directes** entre les systèmes, mais aussi des **boucles de rétroactions complexes, faisant de plus intervenir des flux de différentes natures.**
- Cette vue facilite l'identification d'**opportunités (ex : économie circulaire)** et de **risques** (ex : **défaillances en cascade).**

Scenario catastrophe





Conclusions

- Par cette **étude prospective**, nous avons montré qu'il était possible de qualifier **les impacts du Changement Climatique sur les écosystèmes industriels**.
- Les caractéristiques des systèmes et de leurs interactions au sein de l'écosystème rendent cette **modélisation ardue**, car elles montrent des **interactions complexes**.
- Nous proposons un **outil et une démarche** simplifiant l'assimilation des descriptions remontées par chacune des parties prenantes.
- L'ensemble de cette information est ensuite exploitée de manière **automatique**, afin de fournir des vues pertinentes répondant aux besoins des différents acteurs.

Perspectives

- Cette étude nous a permis de modéliser un écosystème et en conséquence de qualifier l'**exposition** de chacun de ces systèmes à une perturbation.
- L'exploitation de l'**accidentologie NaTech (ARIA)** et des **simulations climatiques du GIEC** nous permettra d'aboutir à une connaissance plus fine de la criticité des **évènements climatiques redoutés**.

Questions / réponses

Evolution des systèmes industriels complexes : gestions des risques et enjeux environnementaux et sociétaux

Laurence Rouïl

Directrice de la stratégie, de la politique scientifique et de la communication

INERIS

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

INERIS
maîtriser le risque pour un développement durable

EVOLUTION DES SYSTÈMES INDUSTRIELS COMPLEXES : GESTION DES RISQUES ET ENJEUX ENVIRONNEMENTAUX ET SOCIÉTAUX

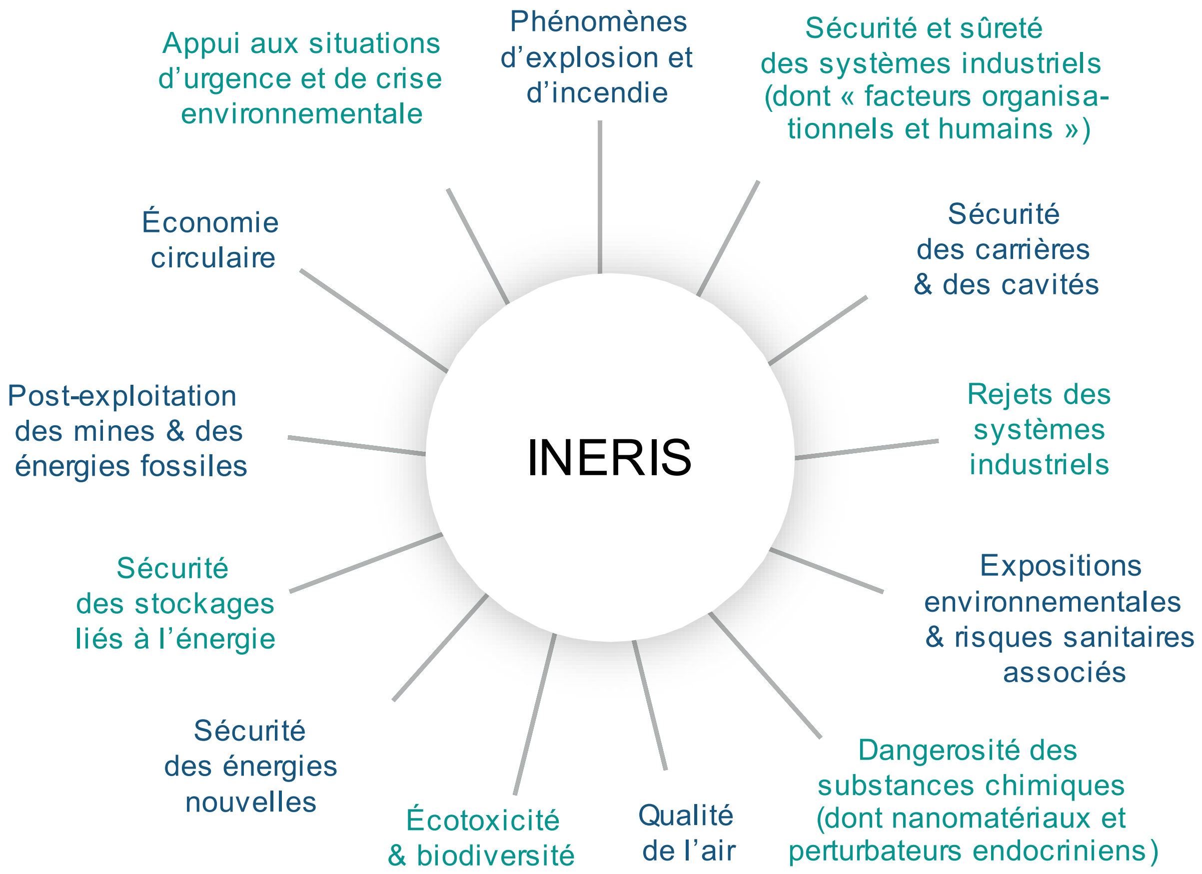
Laurence Rouïl
Directrice de la stratégie, de la politique scientifique et de la communication

-

L'expert public pour la maîtrise des risques industriels et environnementaux

- **EPIC sous tutelle unique du ministère chargé de l'environnement.** Créé en 1990 à partir du Cerchar (Centre d'études et de recherches des charbonnages de France) et de l'Ircha (Institut de recherche en chimie appliquée).
- **Contribuer à la prévention des risques que les activités économiques font peser sur la santé, la sécurité des personnes et des biens, et sur l'environnement.**
- **Environ 550 personnes** (dont environ 30 doctorants).
- **Implantations :**
  - Siège à Verneuil-en-Halatte (Oise), 40 ha dont 30000 m2 de laboratoires ;
  - Équipes basées à Nancy, Aix-en-Provence, Bourges et Lyon.

Les activités clés de l'Ineris



S'intéressent aux interactions entre les systèmes industriels complexes et leur environnement pour réduire et maîtriser les risques qu'ils sont susceptibles de générer

- Dimensions environnementales et sociétales intégrées par nature
- Modèle en trépied: appui aux politiques publiques/recherche/ expertise
- Peuvent être approchées par la certification, la normalisation voire la réglementation

Digitalisation et risque industriel

L'usine du futur ..

- Basée sur la mise en œuvre de technologies numériques qui permettent des gains de productivité et l'optimisation des fonctionnements par un monitorage en temps réel

- Robotique, objets connectés, intelligence artificielle, modélisation..

- Nouvelle dimension du risque industriel (cybersécurité, IA de confiance..) à intégrer dans les démarches d'analyse des risques liés à la sureté et à la sécurité des installations

Thèse de Tamara Oueidat (Univ Grenoble/Ineris - Juillet 2022) / *A new model-based risk analysis approach that generate cyberattacks scenarios and combine them with safety risks*
https://hal.archives-ouvertes.fr/hal-03355097/document

Prise en compte des enjeux environnementaux

Une double perspective

1/ Prise en compte des risques naturels et climatiques dans l'analyse de la sécurité des systèmes industriels

Problématique « Natech » qui soulève des questions de recherche, par exemple sur :

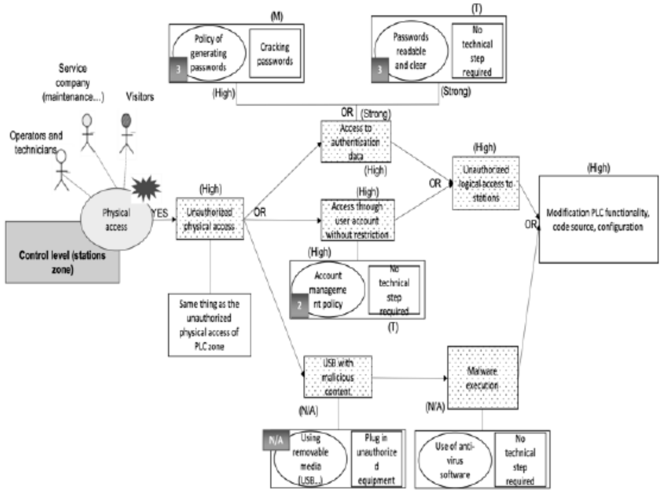
- Modélisation des processus de résilience d'équipements industriels soumis à des évènements extrêmes
- Modélisation des dépendances et des effets cascades potentiellement associés aux évènements Natech.

2/ Réduction des impacts environnementaux et sanitaires des activités industrielles par la maitrise des risques et des pollutions qu'elles sont susceptibles d'induire.

Les apports du numérique

Quelques exemples …

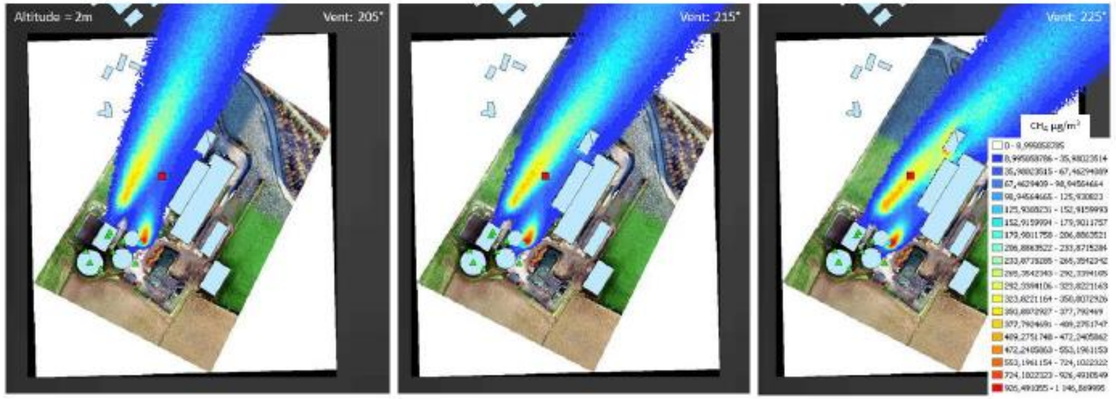
- **Modèles et jumeaux numériques** permettent de concevoir et d'évaluer la probabilité de situations accidentelles afin de les prévenir et de définir les barrières les plus appropriées



Source : Oueidat et al, 2021

- Modèles permettent d'évaluer les impacts sanitaires et environnementaux **de projections et scenarios d'activité industrielle** et de simuler l'efficacité de mesures de mitigation

- Systèmes couplés **Surveillance environnementale/modélisation inverse** permettent de détecter des dysfonctionnements ou des sources diffuses afin de réduire l'empreinte environnementale
  - ➢ Systèmes de plus en plus intégrés à l'échelle de l'installation



Exemple : projet Méthanemis (financé par ADEME)

Prise en compte des enjeux environnementaux et sociétaux

Quels outils ?

- Nouvelles technologies de surveillance permettant d'élargir le spectre de données disponibles et d'intégrer une composante « temps réel » dans l'évaluation des impacts: nouvelles technologies de capteurs, drones instrumentés, capteurs citoyens, mesure et observations satellitaires…
  - Multiplication des données disponibles et leur traitement numérique (assimilation dans les modèles, IA) permet une meilleure description des phénomènes. Point de vigilance sur les incertitudes des mesures pouvant couvrir un large spectre de valeurs
  - Conception de système intégrés capables d'adapter les cycles de fonctionnement selon les impacts observés: verrous technologiques et questions de standardisation, de gestion des incertitudes..
- Normalisation, certification des systèmes pour une dans une logique de sureté, de qualification des barrières, mais aussi de moindre impact environnemental
- Une attente sociétale forte: le concept « safer by design » qui vise à minimiser les impacts sanitaires et environnementaux dès la conception d'un produit innovant, et donc à améliorer le rapport risques/bénéfices sur l'ensemble de son cycle de vie : un espace où le développement technologique fait écho aux besoins de la société.

Pour résumer …

- La prise en compte des préoccupations environnementales et sociétales dans la conception de nouveaux systèmes industriels s'impose pour partie par la réglementation et la normalisation, et peut être stimulée par la certification
- La digitalisation des systèmes industriels ouvre des perspectives en termes d'assimilation et de traitement de données (et peut-être à terme de données citoyennes) qui faciliteront cette prise en compte : surveillance environnementale/modélisation inverse, études de scénarios, analyses d'incertitudes ….
- Les concepts tels que le « safer by design » permettent désormais d'intégrer ces enjeux dès la conception des systèmes
- Néanmoins la digitalisation des systèmes industriels peut induire de nouvelles vulnérabilités des systèmes industriels qu'il convient de bien appréhender dans les méthodes d'analyse et d'évaluation des risques

- Ces questionnements sont au cœur des missions de l'Ineris tant au travers de ses travaux de recherche et d'appui aux politiques publiques que par ses études pour les acteurs économiques.

RÉPUBLIQUE FRANÇAISE
Liberté
Égalité
Fraternité

INERIS
maîtriser le risque
pour un développement durable

Merci de votre attention !

Laurence.rouil@ineris.fr

Questions / réponses