

Strengthening the generative power of a scientific and industrial ecosystem: the case of the SystemX Institute for Technological Research (IRT), a "double impact Research and Technology Organization (RTO)"?

Agathe Gilain, Pascal Le Masson, Benoit Weil, Nafissa Jibet, Patrice Aknin, Alexandre Bekhradi, Paul Labrogere

▶ **To cite this version:**

Agathe Gilain, Pascal Le Masson, Benoit Weil, Nafissa Jibet, Patrice Aknin, et al.. Strengthening the generative power of a scientific and industrial ecosystem: the case of the SystemX Institute for Technological Research (IRT), a "double impact Research and Technology Organization (RTO)"?. EURAM - European Academy of Management, Jun 2022, Zurich, Switzerland. hal-03686580

HAL Id: hal-03686580
https://hal.science/hal-03686580

Submitted on 6 Jun 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Strengthening the generative power of a scientific and industrial ecosystem: the case of the SystemX Institute for Technological Research (IRT), a "double impact Research and Technology Organization (RTO)"?

Agathe Gilain[1], Pascal Le Masson[1], Benoît Weil[1], Nafissa Jibet[1], Patrice Aknin[2], Alexandre Bekhradi[2], Paul Labrogère[2]

[1] Center for Management Science, i3 UMR CNRS 9217, Mines ParisTech, PSL Research Univ., France
[2] IRT SystemX, 2 boulevard Thomas Gobert. 91120 Palaiseau, France

Abstract

Research and Technology Organizations (RTOs) are agents which conduct 'extra-university research' at the boundary between industry and science, acting as an intermediary between the two. Their expected impact is primarily industrial: they are supposed to support and enhance the competitiveness and innovation capabilities of industry. RTOs position of intermediary between science and industry is delicate, since their role is neither to substitute for the industrial partners who conduct their NPD projects and develop innovations, nor to substitute for the conduct of basic research by universities. In particular, one major pitfall for RTO pointed out by the literature is the risk that the outputs of RTOs activities are too research-oriented and fail to meet industrial needs. In this context, the literature tends to recommend that to remain manageable, the intermediation role of RTO between science and industry should be limited to situations of low/moderate uncertainty. The resulting impacts will be modest, but under control for the RTO and highly-valued by industrial firms.

This paper focuses on the French IRT (Institute for Technological Research) SystemX that seems to stand out within the portray of RTOs. Created in 2012, SystemX conducts collaborative research projects aimed at accompanying and accelerating the transformation of industrial sectors in the face the digital transition. Internally, SystemX has intuited that it is inventing a new form of science-industry coupling. Thus, this paper involves mobilizes the theoretical frameworks of design theory, with the aim of characterizing SystemX model of action within its industrial and scientific ecosystem, and testing the hypothesis according to which SystemX has developed capabilities to manage situations the level of uncertainty of which goes beyond moderate uncertainty.

The study reveals that SystemX manages science-industry couplings which do not only involve moderate uncertainty, but also unknowns, associated with which there is a high potential of 'double impact' (simultaneously a scientific and an industrial impact). SystemX is able to articulate the action model associated with these science-industry couplings in the unknown with three other action models (involving lower degrees of unknown). An in-depth case study focusing on one SystemX project shows that the implementation of the four action models and their articulation requires methodical and progressive processes of structuring and creating knowledge: these processes allow the construction (and not the simple identification) of common locks and new disciplines in the unknown. These could be seen as first insights regarding the conditions required for 'double impact RTOs'.

1. Introduction: the field of operation of successful RTOs at the frontier between science and industry: a restriction to low/moderate uncertainty situations

The term Research and Technology Organizations (RTOs) refers to agents which carry out 'extra university research' (Arnold et al., 2010): these include research institutes such as the Fraunhoffer-Gesellschaft (created in 1949, and gathering 57 Fraunhoffer Institutes in Germany), the GTS System (gathering several authorized institutes in Denmark, the first of

which was established in 1906), the SINTEF Group (created in 1950 in Norway), the IRECO Group (created in 1997 in Sweden), VTT (created in 1942 in Finland), the TNO (Netherlands, created in 1932), the KIST (created in 1966 in Korea), ITRI (created in 1873 in Taiwan), SISIR (created in 1963 in Singapore), etc.

RTOs are major components of National[1] Innovation Systems that are positioned at the frontier between academia and industry (Arnold et al., 1998). They develop links with academia, for example in the framework of joint research projects with universities, through employee mobility, or by providing universities with information on industrial needs (Aström et al., 2008). And they develop links with industry, their 'predominant activity [being to] provide research and development, technology and innovation services to clients (industrial partners, governments, etc.)' (EARTO, cited in Arnold et al., 2010), in order to enhance the innovation capabilities and the competitivity of these latter (Arnold et al., 2010).

Bridging academia and industry together is specifically part of the RTOs' mission (Aström et al., 2008). As actors enabling their industrial partners to access external knowledge, RTOs are open innovation intermediaries in the sense of Howells (2006): they constitute a specific kind of open innovation intermediaries, which have the particularities of (i) acting between science and industry, and (ii) being 'active' in the intermediation process (Barlatier et al., 2016 ; Arnold et al., 1998 ; Readman et al., 2015). This second particularity refers to the fact that RTOs are 'innovation active'[2] (Readman et al., 2015): they are not solely brokers transferring knowledge available in the academic world to industrial actors with a logic of transaction cost optimization[3]: they are actively involved in the generation of the knowledge and technologies (Barlatier et al., 2016). Thus, beyond a simple transfer, RTOs need to set up 'their own dynamic, based on acquiring, maintaining and supplying technologies and technology-related services which industry needs but cannot readily access in-house' (Arnold et al., 1998).
This means that the relationship between a RTO and industry (e.g. the service provided by a RTO to its industrial partner) involves both commercial activities related to the transfer of the technology (i.e. non R&D activities), and R&D activities. Some authors call 'the R&D intensity' the proportion of R&D activities contained in the total activities involved in the relationship.

Being able to combine R&D and non-R&D activities in their relationship to industry is central in the definition of RTOs. And it also appears to represent major challenges for them. Indeed, a few RTOs are successful and have national, even international recognition. But numerous turn out to be unsuccessful, with 'irrelevance for industrial partners' being one major form of failure (e.g. Rush et al., 1996 ; Arnold et al. 1998): there are reports of firms complaining that RTOs services are too much R&D-centered, to the detriment of implementation and marketing (Santamarìa at al., 2009, cited in Barge-Gil and Modegro, 2011). The uncertainty inherent in the R&D-part of the service increases the risk that the final results of the collaborative project will not satisfy the industrial partner (Arnold et al., 1998). Thus, Arnold et al. (1998) point out that RTOs need to be aware of where their cursor is in terms of R&D intensity and, given this

[1] One can also note that there exists RTOs part of regional innovation policies, for example in Spain (Valence region, Basque country (Albors-Garrigos et al., 2010))
[2] Readman et al. (2015) use the term 'innovation in the case of UK RTOs
[3] Barlatier et al. (2016) explain that in Perkman et Walsh's (2007) typology of academia-university couplings, the nature of academia-industry couplings developed by RTOs corresponds to 'strong' couplings (involving research partnerships, R&D services, etc.), contrary to the nature of the couplings organized by another kind of intermediary, TTOs (Technology Transfer Offices), which corresponds to 'weak' couplings (business relations only, with the objective of optimizing transaction costs)

intensity, deploy appropriate strategy and managerial principles (adapted to the level of uncertainty).

Several studies have sought to describe the factors which determine the success of an RTO (Rush et al., 1996 ; Arnold et al., 1998 ; Barge-Gil and Modrego, 2011). In an analysis of nine successful RTOs, Arnold et al. (1998) note that the most successful RTOs 'carry out little advanced research', that they rather focus on 'highly specialized technical task'. With this focus, their impact remains 'modest', but 'highly valued by industry' (Arnold et al., 1998). In other words, this suggests that the field where RTOs successfully operate is a field where the R&D intensity remains moderate. In line with this result, in a quantitative statistical study, Barge-Gil and Modrego (2010) find that the R&D intensity[4] of the service provided by the RTO to its industrial partner has an inverted U-shape influence (i) on the economic impact of the service for the industrial partner, (i)) on the technological impact for the industrial partner, and (iii) on the impact on investment strategy of the industrial partner: beyond a certain level of R&D intensity, the benefits of the collaboration from the viewpoint of the industrial partner decrease.

Several factors determining the industrial performance of a RTO have been highlighted (Barge-Gil and Modrego, 2010 ; Albors-Garrigos et al., 2010) among which: the closeness of the RTO with academic and industrial actors, the longevity of the relationship between the RTO and its industrial partners, the motivations of the industrial partner (scientific motivations, as opposed to cost-and-risk-mutualization-oriented motivations), the skills of the employees at the industrial partners, the communication between the RTO and its industrial partners, etc. Barge-Gil and Modrego (2010) also note that the budget of the collaboration does not statistically explain the success of the collaboration from the viewpoint of the industrial partner. Beyond identifying factors, some research work have sought to describe what these factors might be in terms of management and organizational principles: for example, Villani et al. (2017) propose to describe *how* RTOs establish close links both with industrial and academic partners and bridge them together through the theoretical framework of the 'proximity perspective'.

Given this picture of the RTOs situation, this paper aims to focus on two questions:

1. Could the field where RTOs successfully operate (i.e. the spectrum of situations manageable by an RTO) be extended to situations with 'more / higher uncertainty', and generate impacts the extent of which goes beyond 'modest impacts'? Does there exist RTO which successfully operate under high uncertainty, beyond the successful RTOs that have been surveyed thus far?

   In this regard, the literature has already shown the existence of intermediaries which operate beyond the « modest uncertainty »: indeed, previous research works (Agogué et al., 2013 ; Agogué et al., 2017) have characterized a particular form innovation intermediaries called 'architects of the unknown': these latter carry out not only transfer and network activities, but play a leading role in structuring a collective exploration, and guide knowledge creation in a situation involving heterogenous actors and the absence of a well-identified and consensual purpose (i.e. they act in the unknown). The existence of such intermediaries in the unknown invites the question of whether 'RTOs in the unknown' might also be possible.

[4] i.e. the share of R&D in the total service

2. If such RTOs exist, how do they operate in the face of high uncertainty / in the face of the unknown? What is the nature of the 'high uncertainty' in question? According to which managerial and organizational principles do these RTOs operate?

In order to explore these questions, this paper studies a French RTO: SystemX. Created in 2012, SystemX conducts collaborative R&D projects, including industrial use case-driven projects, in the framework of collaborations with industrials and academics involving multiple heterogenous industrial sectors and multiple scientific domains. In early 2021, the scientific director of SystemX contacted the Centre of Management Science because he wanted to explore the hypothesis that SystemX was creating a new and original way of coupling science and industry within its ecosystem of industrial and academic partners. He was willing to have a research study that would characterize the role of SystemX within its ecosystem and allow to test this assumption.

This paper is structured as follows: Section 1 having given a first, 'macro' picture of RTOs at the frontier between science and industry described in section 1, Section 2 will review the literature to describe in more detail the micro-activities carried out by RTOs, paying attention to the potential of impact, the degree of uncertainty and the associated managerial principles. Section 3 is dedicated to the methods used (single case study, carried out in the frameworks of design theory). Section 4 presents the results from the in-depth study of SystemX, which are then discussed in Section 5.

2. Literature review: a finer grained description of RTOs-driven industry-science couplings and associated activities

2.1. A lack of managerial principles for RTOs in the face of the unknown

The literature distinguishes between three kinds of activities that can be conducted by a RTO (e.g. Arnold et al., 2010 ; Aström et al., 2008). These latter are :
(1) "Exploratory research and development to develop an area of capability of a technology platform" (Arnold et al., 2010, pp 10-11)
(2) "Further work to refine and exploit that knowledge in relatively unstandardised ways, often in collaborative projects with industry" (Arnold et al., 2010, pp 10-11)
(3) "More routinised exploitation of the knowledge, including via consulting, licensing, spin-off company formation" (Arnold et al., 2010, pp 10-11)

These activities can be seen as elementary activities that are non-mutually exclusive and that can be conducted by a RTO either simultaneously or successively. Aström et al. (2008) namely present these three kinds of activities as the successive stages of a RTO development cycle: having previously developed knowledge and competences in the framework of the first and second type of activities is a precondition for a RTO to consider commercial activities. In addition, even once the RTO has reached the commercial type of activities, it needs to renew its competences and capabilities on a continuous basis, through the first and second type of activities: this is what distinguishes a RTO from private consultancy (Aström et al., 2008).

In what follows, we 'reformulate' these activities, describing in more details the **nature of the science-industry coupling** driven by the RTO. This leads us to distinguish between four action models for RTO. The point in carrying out this reformulation is that, for each identified action model, it allows us to describe:

- the **nature and the extent of the academic and / or scientific impact** that can be expected
- the **intensity of uncertainty** associated with the activity
- the **managerial challenges** associated with the kind of relationship and the level of uncertainty that goes with it, and if there are any, the possible avenues in terms of the **available managerial levers** to address them

• Action model 0: active intermediation, with a single industrial client (= matching the needs of an industrial partner with knowledge/skills available in the research world)
This first action model corresponds the situations where the RTO, in the framework of the 'active intermediation' (Barlatier et al., 2016 ; Arnold et al., 1998) mentioned in Section 1, provides an industrial partner with a service involving a transfer of knowledge, technologies, etc.…, which the industrial needs and is not able to develop alone, because it lacks the necessary knowledge, financial means, or infrastructure. These situations often concern SMEs. The RTO activity consists in (actively) **matching the needs of an industrial partner with knowledge/skills available in the research world**[5]. The "More routinised exploitation of the knowledge, including via consulting, licensing, spin-off company formation" described by (Arnold et al., 2010, pp 10-11) falls into this action model.

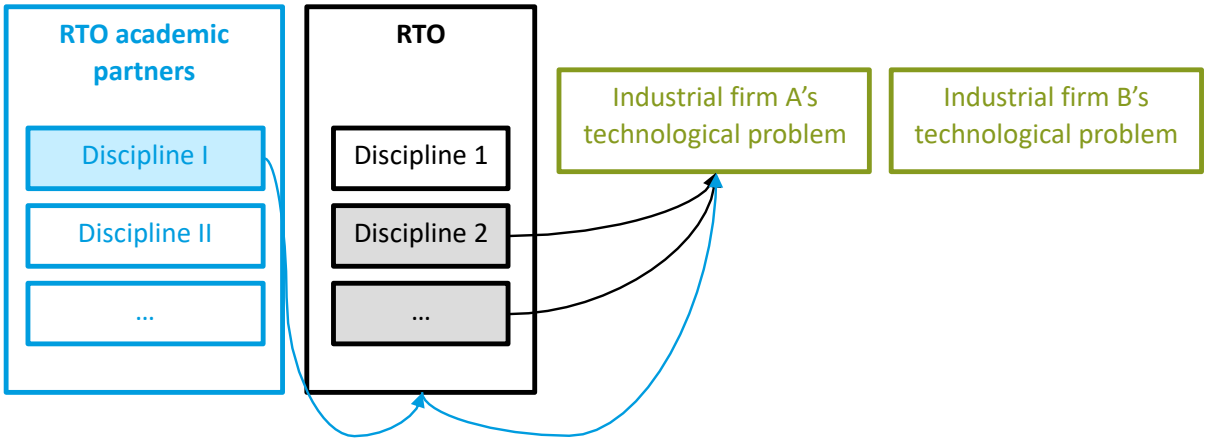


Figure 1. Action model 0: active intermediation, with a single industrial client (= matching the needs of an industrialist with the knowledge/skills available in the research world)

As mentioned in Section 1, it is largely acknowledged in the literature devoted to RTOs that these activities will be successful (i.e. the client will be satisfied) if the **degree of uncertainty remains moderate** (e.g. Rush et al., 1996). Research works regarding other types of innovation intermediaries the role of which is to match the needs of a problem seeker with the competences of problem solvers also support this idea: in the case of the Innocentive Open Innovation platform, Sieg et al. (2010) highlight that the match will be successful provided two condition are satisfied: (1) the industrial problem is known and well-formulated and (2) the technological and scientific knowledge necessary to solve the problem are available. These conditions correspond to situations with a low degree of uncertainty. Meeting these conditions restricts the operational field of an RTO to a limited spectrum of situations. And as already noted in Section 1, these conditions also correspond to a modest impact (Rush et al., 1996), of the order of the resolution of a singular problem encountered by an industrial firm. And no particular academic

[5] Highly specialized tasks and services, advanced engineering, experimental development, design work, process improvement, problem solving (Rush et al., 1996) fall into this category of RTO activities. Activities such as operational services, testing of standards or certification, risk management for the industrial partner (Readman et al., 2015) also fall into this category of activities.

impact can expected, since one mobilizes and exploits knowledge and skills that are already available.

Beyond this action model 0, it is possible to envisage three additional RTO activity models (some of which are mentioned in the literature), and which can be seen as models the operational conditions of which correspond to a relaxation of the two constraints of Sieg (2010) (the constraints are first relaxed one by one (action models 1 and 2), then both together (action model 3)). The relaxed conditions allow to consider:

- a wider spectrum of operation situations;
- with more interesting potential impacts;
- but with a much greater degree of uncertainty to manage: situations where (i) the knowledge necessary to develop the problem are unavailable and need to be generated and / or where (ii) the problem to be solved is unidentified (i.e. no project target identified) can be considered as situations "in the unknown": the managerial issues will not be about reducing uncertainty and making optimized decisions related to already identified, but uncertainly-known states of the world: they will be about structuring the unknown, i.e. building new states of the world and new decisional alternatives better than the ones that already exist (Le Masson et al., 2018).

• Action model 1: active intermediation, in the framework of a multi-industrial-partners project

While historical RTOs tended to be specialized in one industrial sector, many have become multi-sectorial. This phenomenon is namely observed the case of UK RTOs (Readman et al., 2015). Arnold et al. (2010) also report collaborative, multi-sector research projects conducted by RTOs.

"Further work to refine and exploit that knowledge in relatively unstandardised ways, often in collaborative projects with industry" (Arnold et al., 2010, pp 10-11) can be seen as belonging to this action model.

The potential impact associated with this action model is more than a modest problem resolution: namely, a generic impact crossing several industries can potentially be attained. But this model also involves additional managerial challenges, due to the cross-industry aspect. In particular, previous works have shown that in the framework of cross-industry collaborations, formulating a common problem is not trivial: a 'common purpose' needs to be generated through a specific design process (Gillier et al., 2012). In other words, in a cross-industry context, Sieg et al.'s (2010) condition requiring a well-formulated problem for the intermediation is not satisfied. The formulation of a common problem represents an unknown to explore.

The cross-industry situation also raises challenges related to the capacity of an industrial partner to absorb results and knowledge that are valid in another sector: previous works have shown that intermediaries can play an interesting role in this regard (Gassmann and Enkel, 2010) (i.e. having an intermediary involved in a cross-industry project can be seen as a plus, compared with cross-industry projects involving only industrials. But this also represents specific capabilities to acquire from the viewpoint of a RTO.

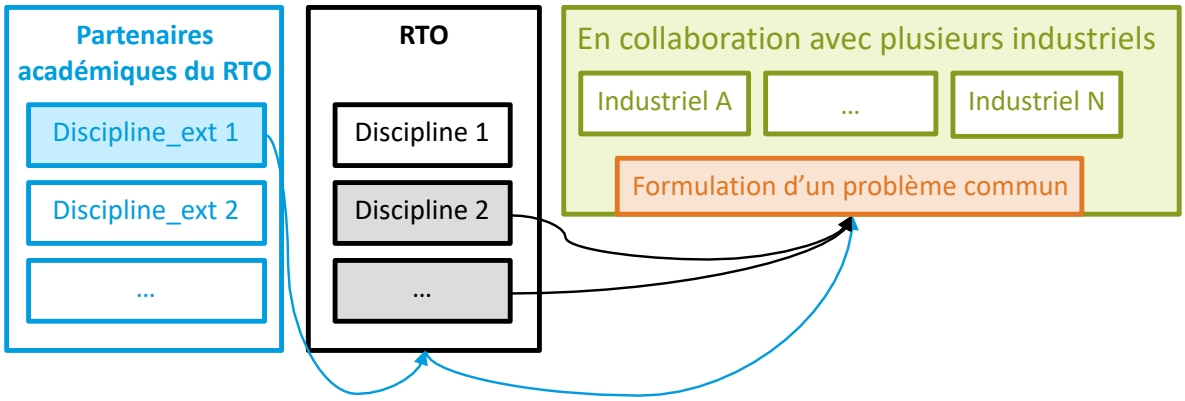


Figure 2: active intermediation, in the framework of a multi-industrial-partners projects

• Action model 2: exploration of new disciplinary fields and new expertise with a single industrial partner

This model includes the RTOs activities related to the exploration of a scientific / technological discipline, which is new to the industrial partner and may be more or less new to the RTO (so possibly in collaboration with one or several of its academic partners). We build this model with the assumption that the industrial partner is able to formulate its needs or problem.

Both "Further work to refine and exploit that knowledge in relatively unstandardised ways, often in collaborative projects with industry" and "Exploratory research and development" described by (Arnold et al., 2010, pp 10-11) can be seen as belonging to this action model.

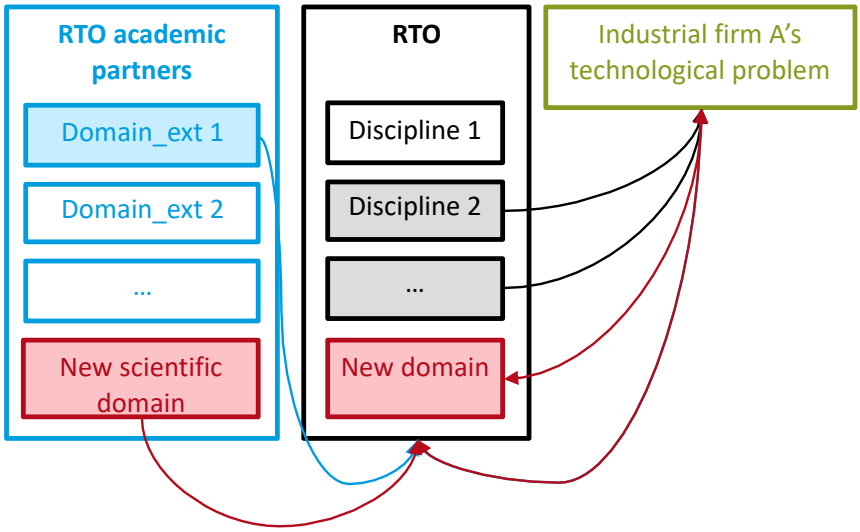


Figure 3: exploration of new disciplinary fields and new expertise with a single industrial partner

The potential impact associated with this action model goes beyond a modest 'problem resolution' for a single industrial firm. An academic impact can be expected, associated with the exploration of the new scientific domain itself. In addition, the structuring of the new disciplinary field can entail a reconfiguration of already-existing disciplines (Cabanes, 2017): this can be seen as an academic impact. Associated with this reconfiguration, a renewal of industrial objects can be considered (Cabanes, 2017) (i.e. potential industrial impact).

From the viewpoint of Sieg et al.'s (2010), the condition of the availability of the necessary knowledge to address the industrial problem is not met.

Managerial challenges can be highlighted, namely managerial challenges related to the capacity of the industrial partner to absorb results associated with a domain of expertise that is new to it: in this regard, recent research works (Kokshagina et al., 2017) have shown that innovation intermediaries can carry out a specific role to compensate overcome these difficulties [à détailler]. This suggests that RTOs should have the specific capabilities required to carry out such a more demanding role in the unknown.

• Action model 3: exploration of new disciplinary fields and new expertise with a multiple industrial partners

This action model is the sum of the two previous ones (multiple industrial partners from heterogenous sectors and the exploration of a new scientific discipline, new to the industrial partner and more or less new to the RTO). Both "Exploratory research and development" and "Further work to refine and exploit that knowledge in relatively unstandardised ways, often in collaborative projects with industry" described by (Arnold et al., 2010, pp 10-11) can be seen as belonging to this action model.

This model is high potential, with the sum of the potential impacts associated with model 2 and model 3. But this model is also very challenging and demanding from a managerial point of view.

It involves the sum of all the challenges and difficulties (not exhaustively) listed for models 2 and 3. In particular, it involves the risk that a project that is too research-oriented will not meet the needs of industry (which the literature devoted to RTOs regularly warns about). And conversely, it also involves the risk that a project that is too industrial-use-case-driven will not produce high quality academic outcomes.

In summary, the four models described in this subsection depict a situation where:
as one moves from model 0 to model 3, the dose of unknown to explore increases (from no unknown in model 0, to problem-formulation-related unknown and / or new scientific discipline unknown to explore). As the dose of unknown to explore increases, so does the magnitude of the potential industrial and academic impacts. However, situations with high unknowns and high potential, in particular model 3, seem to incorporate significant difficulties and pitfalls, for which the management principles that would allow them to be addressed and kept under control are challenging / demanding to put in place and are not necessarily available. Yet, recent works (Plantec, 2021) devoted to double impact science-industry couplings in situations with two designers (one academic actor and one industrial actor), suggest that this situation is not ineluctable. The following subsection describes these results.

2.2. The possibility of particular science-industry coupling that explore the unknown to generate double academic and industrial impacts simultaneously

With a model of science-industry coupling built on C-K theory (Hatchuel and Weil, 2003), research works (Plantec, 2021) highlight the conditions under which a simultaneous double impact (both academic and industrial) can be generated in the framework of the collaboration between one industrial actor and one academic actor: this very condition is that the two partners

bidirectionally exchange bricks of knowledge that are independent relatively to the receptor's knowledge base.

This model has been illustrated with the case CrisprCas9 (Plantec, 2021 ; Plantec et al., 2019a). Simultaneous double impact has also been highlighted in the case of French CIFRE collaborative PhD program: while in this kind of program where the PhD student is employed by the industrial firm, one expects industrial-objective-driven applied research, and by implication, one expects primarily industrial impacts, these collaborations turn out to generate both high-rank academic publications and industrial impacts (Plantec et al., 2019). A study of Nobel Prizes also showed a significant, and steadily increasing with time proportion of Nobel Laureates, had a determining contact with industry before receiving the Nobel Prize (Planted et al., 2019).

These results invite to phrase the following question: in the case of RTO-driven science-industry couplings implying industrial partners from several industrial sectors and impliying multi-disciplinary academic situations, what would a "double impact RTO " be? According to what processes and under what conditions?

This paper attempts to shed light on this question by studying in depth the case of the IRT SystemX, which seems particularly appropriate to investigate these questions for several reasons which are detailed in the Section 3.

3. Research questions and methods

3.1. A single-case study method dedicated to an intriguing RTO, SystemX

Created in 2012, SystemX conducts research projects aimed at accompanying and accelerating the transformation of application sectors[6], in the face the digital transition. SystemX operates on four priority application areas, which are multi-industrial sector, and eight scientific domains that cross several sectors. Since 2012, SystemX has completed more than 40 collaborative R&D projects which cross one or several industrial sectors with one or several scientific domains. It has collaborated with about 100 industrial partners and 30 academic partners. In 2021, 150 engineer-researchers and doctoral students are employed by System, and 100 full time equivalents are made available from industrial partners and academics (which corresponds to 200 people made available).

A first reason why SystemX appears relevant to study the questions mentioned above is that within SystemX internal direction, at the scientific direction, there is a 'suspicion / intuition' that SystemX is creating a new and original way of coupling science and industry within its ecosystem of industrial and academic partners. This leads to make the hypothesis that SystemX action model could be original in that it drives double impact science-industry couplings in its ecosystems. (could the double impact model describe SystemX action model? And conversely, could SystemX provide empirical evidence for the existence of double impact science industry couplings in situations involving multiple industrial actors and multiple academic actors? i.e. could SystemX provide empirical evidence for the existence of a double impact RTO?).

[6] 1. aeronautics, 2. automotive, 2. guided transport, 4. maritime industry, 5. mobility and logistics, 6. materials, manufacturing and chemistry, 7. construction, buildings, 8. security and defense industries, 9. digital infrastructures, 10. electrical and electronic industries 11. energy, 12. water and waste, 13. agriculture and food chain, 14. health, 15. finance, banking, insurance

The second reason is that some first empirical elements also invite to phrase this hypothesis: indeed, a rough analysis carried out with traditional indicators shows that out of 27 completed projects, 17 have generated both academic publications and industrial assets classified as high potential by SystemX (Figure 5).

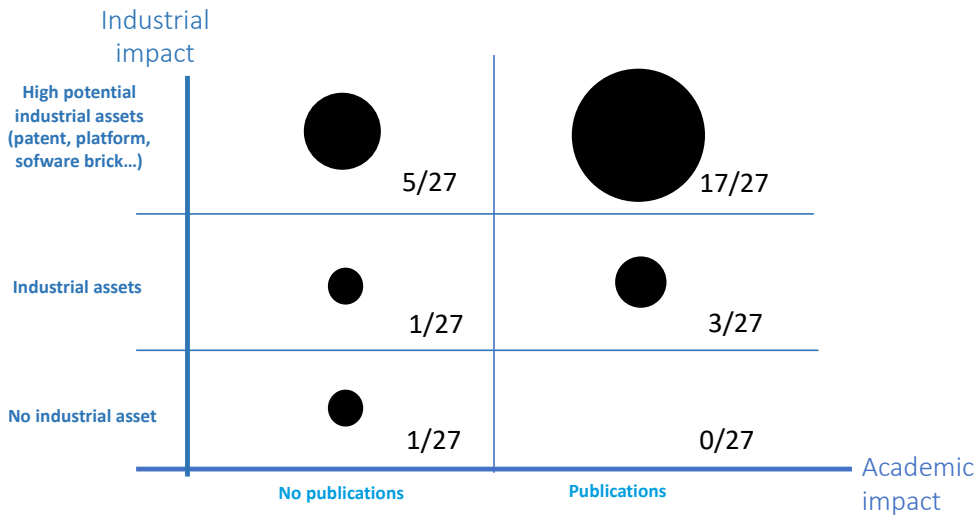


Figure 5. Distribution of 27 completed SystemX projects according to traditional indicators, in terms of industrial and academic impact

This analysis through traditional indicators is insufficient to determine the action model(s) associated with SystemX projects. Among the action models defined in subsection 2.1, is it Model 3? Models 1 and 2 simultaneously deployed? Etc.

These elements make SystemX an intriguing RTO (Siggelkow, 2007). In this context, this paper will carry out an in-depth study to characterize SystemX model, focusing on the following research questions:

• RQ1: Which of the four action models of RTO introduced in subsection 2.1 has SystemX implemented?

In order to address this question, we carried out an empirical study of SystemX functioning and processes, at a macro level. To that end, interviews were realized with the scientific director, the head of the Research and Technology department, and the head of the Strategy and Programs department. Documents (both public and internal documents) describing the functioning of the IRT were analyzed. And the results were presented and validated during regular steering committees.

Analyzed documents	Interviews	Steering committees	Additional observations
Public documents: • Press releases on the launch of new development phases (new roadmaps) • Institutional documents for external communication Internal documents • Annual reports (from 2014 to 2020) • One impact report (2019) • Evaluation Report of the French High Council for the Evaluation of Research and Higher Education (Hcéres) responsible for evaluating French higher education and research structures	Between May 2021 and June 2021 - 1 one-hour-and-a-half interview with the head of the scientific direction - 1 one-hour-and-a-half interview with the head of the strategy and programs direction - 2 one-hour-and-a-half interview with the head of the research and technology direction	3 steering committees (June, July and October 2021)	Scientific and Technical Committee: presentation of the results

Table 1: summary of the data sources mobilized to address RQ1

• RQ2: What mechanisms, processes and conditions allow SystemX to structure the unknown and thus generate a double impact?

In order to address this question, a retrospective analysis of a project considered by SystemX as an exemplary project was carried out, mobilizing the formalism of the C-K theory (Hatchuel and Weil, 2003). As we explain in more details in subsection 4.2, the C-K theory will allow us to capture the mechanisms of knowledge creation and knowledge exchange driven by SystemX. This C-K analysis was carried out with a case study approach:

- three interviews with project members (respectively 2 hours, 1 hour and 1 hour and a half), including a one-hour presentation of a demonstrator resulting from the project;
- documents analysis (project reporting documents, including annual reports ; academic papers published reporting project findings of academic interest).

The results were also presented during the two last steering committees mentioned in Table 1 (July and October), which were attended by the manager of the analyzed project.

4. Findings

4.1 R1: the SystemX model, an original combination of four RTO action models

• Action model 1 (active intermediation, in the framework of a multi-industrial-partners projects) was historically deployed by SystemX

SystemX describes the period 2012-2016 as a 'ramp-up' phase, during which an approach to setting up projects driven by industrial use cases was initiated and formalized (SystemX HCERES report, 2019). This approach involves the three following successive steps:

- the identification of industrial partners who face needs, challenges and are confronted to problematics (called 'use cases') which could be explored by SystemX (the Strategy and Programmes Direction manages this step);
- the identification of relevant academics with respect to the identified challenges (the Scientific Direction manages this step);
- the assignment of SystemX research-engineers on projects, who will work jointly with industrials and academics who would have been made available by the partners of the project (the Research and Technology Direction manages this step).

"The 'use cases', key issues, and the multi-actor and multi-sector nature of the projects motivate the partners to participate" (steering committee 1). During this first phase, SystemX did not focus on commercializing the intellectual property generated in the framework of the projects: its priority was that the use-case-based projects "enable to gain the trust of industrial partners", the targeted manifestation of this trust being that industrial partners having participated in a project would be willing to participate in a subsequent project.

The approach involved in these projects falling into model 1 is a "structured approach, under the form of specifications, deliverables, tasks. It could look like a research contract (i.e. model 0). But the initial specifications intentionally leave degrees of freedom related to what is going to be designed during the project.".

• ***From model 1 to reaching model 3: over time SystemX's skills increased through its engineers-researchers, and SystemX developed (1) an ability to structure scientific and technological roadmaps; and (2) an ability to guide the choice of the disciplines to be mobilized during the project***

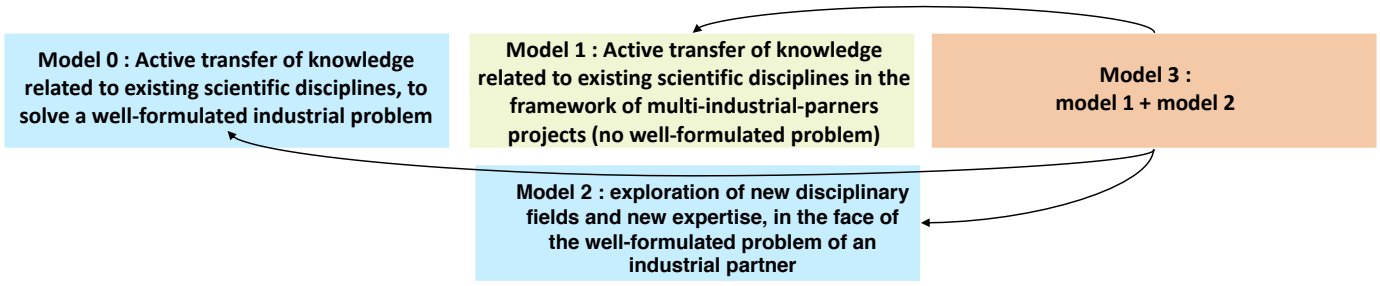
The following example illustrates SystemX's capacity to guide the choice of the discipline, in the framework of a collaborative project: in a project dealing the implementation of the validation process of the ADAS (Advanced Driver-Assistance Systems) in automated vehicles, the software instrumentations available at the industrial partner did not meet the needs: in this context, SystemX has been able to push one of its technological knowledge to develop a specific software (interview).

• ***From model 3, to a situation where model 3 is simultaneously articulated with the three other models***

After having reached model 3, SystemX turns out to articulate it with the three other models:

> - Through scientific resourcing, an articulation from Model 3 (exploration of double unknowns) to Model 2 (exploration of new scientific areas):
>
> In order to reinforce its competences and reach and maintain the excellence which makes it attractive to its industrial partners and to its staff of researchers-engineers, SystemX continuously reinforces its scientific competences. Within the scientific direction, a specific kind of activities has been set up, through which SystemX carries out autonomous explorations (independently of industrial partners). In addition, SystemX starts to initiate some projects with techno-push approaches toward industrial partners.
>
> - Through a more commercial-oriented offer, an articulation from Model 3 to Model 0:
>
> SystemX is now considering activities related to "maturing the objects resulting from a project, beyond the life of this project", with the aim of generating valuable objects. This includes valorization activities, namely intellectual property valorization. In addition, SystemX has developed a new service, that is short-term research service projects provided to a single industrial partner.
>
> - Model 1 (use-case-driven collaborative research projects) remains central: an articulation from Model 3 to Model 1

Following projects which have been carried out according to model 3, SystemX initiates new use-case-driven collaborative research projects, possibly involving the previously involved partners, and also new ones. These Model 1 projects may shift to Model 3 during the course of the project, when SystemX guides the choices of the technological disciplines to mobilize.



Stage 1 : 2012 – 2016 – SystemX historical models: industrial use-case driven collaborative projects

Stage 2: 2016 - .. Over time, increase of SystemX's skills through its engineers-researchers and development of (1) an ability to structure scientific and technological roadmaps; (2) an ability to guide the choice of the disciplines to be mobilised -> Model 3

Current stage: Articulation of Model 3 with the three other models

Figure 6. An original articulation of four action models in SystemX

The main result from this study of SystemX functioning, summarized in Figure 6, is that SystemX action model consists of an original combination of four models. And it carries out activities that involve an exploration of double (industrial and academic) unknowns.

This result leads to the following new (sub) questions: What does the implementation of these models involve? In particular, what does the formulation of the common lock involve? What does the structuring of the new disciplines involve? How is the articulation from M3 to M2, M1 and M0 achieved?

These new questions structure the investigations carried out to address RQ2 (*What mechanisms, processes and conditions allow SystemX to structure the unknowns and thus generate a double impact?*)

4.2 R2: SystemX AMC (Agility Design Margins[7]) project: highlighting the process of building a common lock in the unknown and structuring a new discipline

The AMC project is considered as an exemplary project by SystemX.
We have traced the course of this project with the formalism of the C-K theory (Hatchuel and Weil, 2003), which allows to highlight:

- in the K-space, the initial knowledge bases (SystemX's ; industrial partners' ; academic partners');
- in the C-space, the problems and locks formulated and explored by the project;
- in the K-space, the newly generated knowledge, and its impact on the formulation explored problems (locks) during the course of the project, as well as its impact on the initial knowledge bases

[7] Agilité Marges de Conception

Identifying the new technological and scientific knowledge generated by the project, as well as knowledge gaps highlighted by the project also allows to investigate and discuss their possible / potential role at the end of the project:

- among the new knowledge produced, what could be subject to further maturing and valorization, with a perspective of commercialization, in the framework of the model 0?
- among the new knowledge produced / the highlighted knowledge gaps, what calls for further scientific explorations, in the framework of model 2?
- among the new knowledge produced and among the highlighted knowledge gaps, what invites to launch a new industrial-use-case driven project, with the same industrial partners and / or new ones, in the framework of model 1?

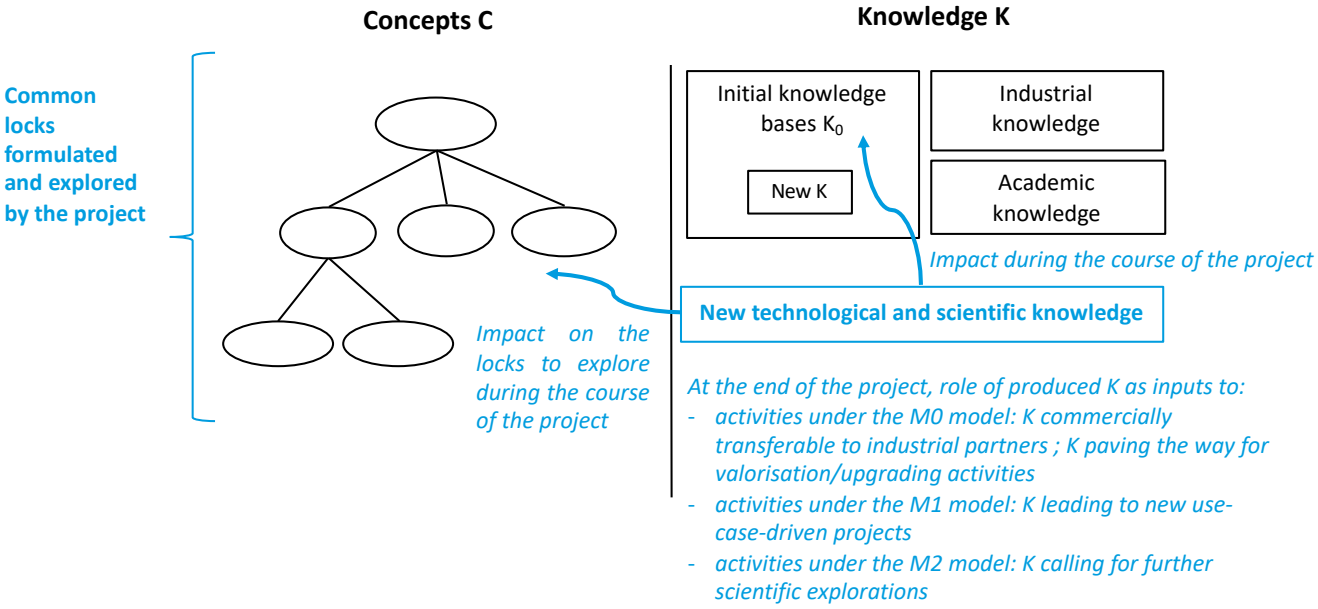


Figure 7. Analysis of SystemX projects through the formalism of C-K theory

The AMC project was conducted between February 2017 and September 2021 in SystemX. It was set up as a use-case-driven project (Model 1). A use case from the automotive sector was proposed by Renault, Stellantis and Valéo. A use case from the aerospace sector was proposed by Airbus. Software editors (DSP, Sherpa and Siemens) and academic partners (the CERMICS[8]; Supmeca) also participated in the project. This project is a follow-up to two past SystemX projects.

The analysis of the AMC project through the formalism of the C-K theory led to identify three distinct phases in the project:
• Phase 1: an extension of the project set-up, leading to structure an initial knowledge space and generate a first formulation of associated problems and locks to be explored;
• Phase 2: exploration of concepts and production of new knowledge: construction of a common lock and a new discipline (model 3);
• Phase 3: several forms of rebounds possible, under the different models (a son project (model 1); generic specifications of the simulation architect's tools (model 0); scientific explorations (model 2)

[8] "Centre d'Enseignement et de Recherche en MathématIques et Calcul Scientifique", i.e. "Center for Training and Research in MathematIcs and Scientific Computing", Ecole des Ponts ParisTech

which are detailed in what follows.

• Phase 1 - an extension of the project set-up, leading to structure an initial knowledge space and generate a first formulation of associated problems and locks to be explored

The initial objective of the AMC project was to "reinforce the link between the world of system engineering and the world of digital simulation, with the aim of enabling agility in design processes based on multidisciplinary simulation" (AMC project succinct objective in internal documents). Put differently, the objective is to reinforce the link between system engineering and digital simulation, so that simulation can better contribute to address development (contemporary) problems and challenges, and in particular contribute to make development processes more agile.

The strengthening of the link between systems engineering and simulation was addressed by the objective of formalizing a set of activities related to the design of the simulation architecture, which until now have been carried out in a non-tooled, informal and implicit manner. These activities are **the formulation of the simulation demand, the building of the simulation architecture, the selection of the simulation models the constitute it, and the simulation means are non-tooled activities[9].** These activities and the associated decisions are carried out through emails, informal meetings, etc. that are neither traced nor documented. It was acknowledged both from the viewpoint of SystemX and industrial firms that this represents a "loss of revenue", in terms of agility, development time, etc., especially because simulated models that have been (informally) chosen and used are never reused.

In this context, SystemX makes the following observation in terms of knowledge: « We knew the upstream process[10] and downstream process[11] of the simulation architecture design activities. We knew that we wanted to build this "middle" process but we didn't know what it would be » (AMC project manager).

Only an unclear, and unexplorable concept (represented in the C-space of Figure 7) can be associated with this observation: "building the process of the middle".

[9] The process in which these informal activities are led is summarized by the upper part of Figure 7: A product / system architect, responsible for defining product functions and their allocation to physical components, may be confronted to architecture-choice related questions, with respect to which simulation could provide some answers. In this context, a system architect who has simulation needs will formulate a simulation demand. A simulation architecture made of interconnected elementary simulation models will be chosen will be build, and the necessary simulation means will be selected. Then, simulation experts will develop the methods and algorithms necessary to carry out the simulation, which will be implemented. It will provide results which will guide the decisions of the system architect.

[10] That is the modelling of the system, in the form of a system architecture (e.g. with Model-Based System Engineering approaches)

[11] That is the execution of the simulation by simulation experts

<u>Phase 1:</u> as a continuation of the project set-up: structuring of initial knowledge and formulation of associated lock

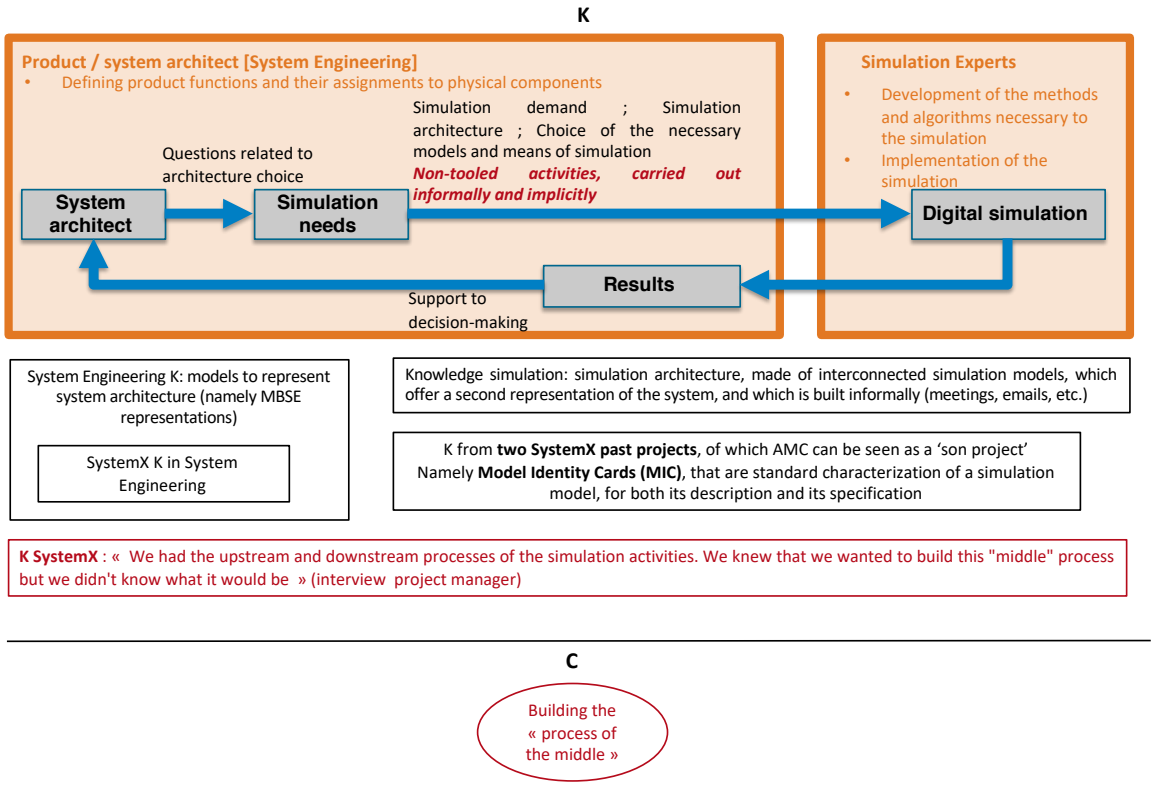
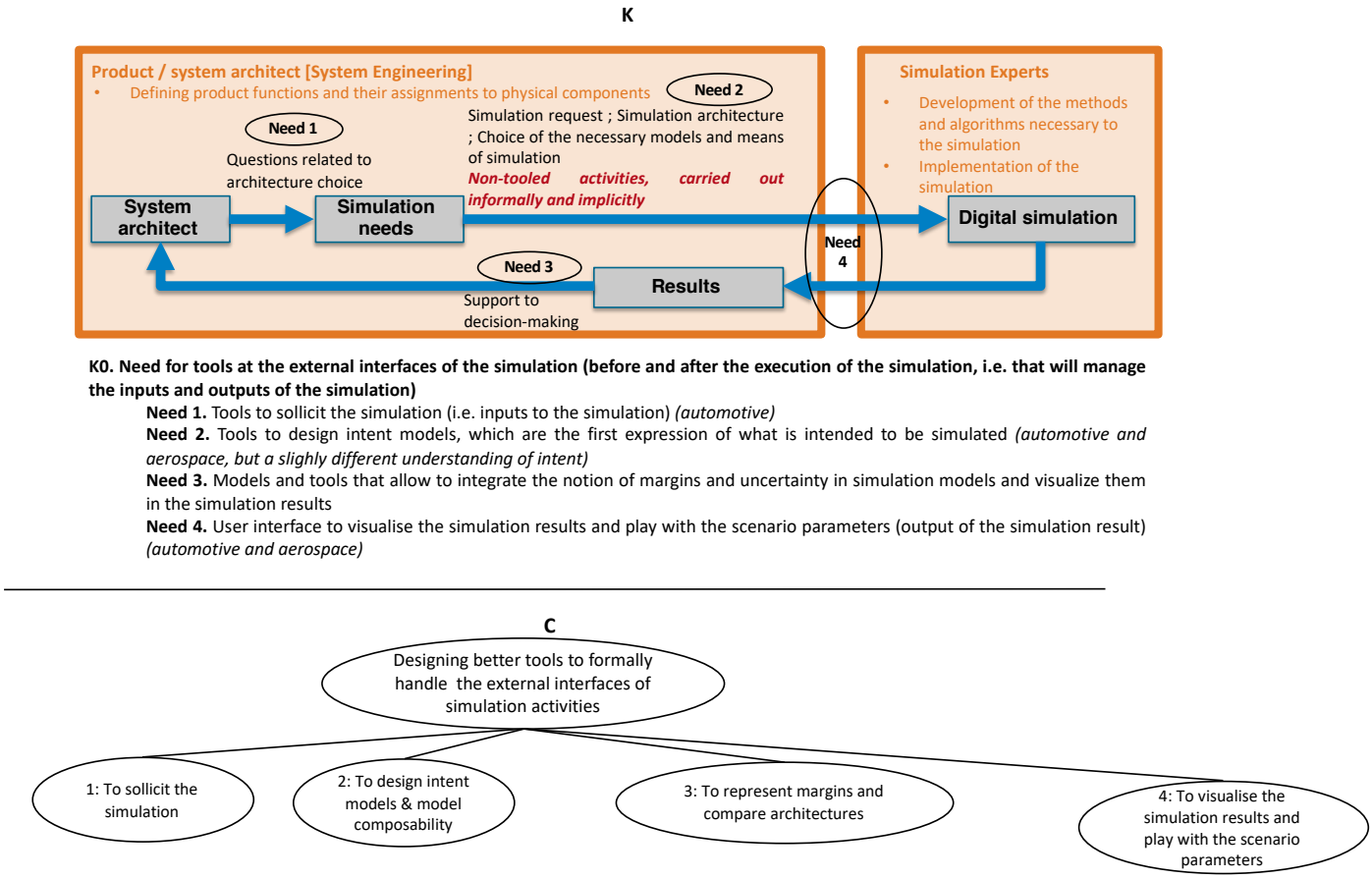


Figure 7. AMC project initial K-space and C-space, from the viewpoint of SystemX

In parallel, industrial partners expressed a need to equip the activities 'around' the simulation: tools for the system architect/simulation architect relationship; description of the simulation models to be chosen, especially intention models), for the actors from the automotive industry ; decision cockpit for the system architect; Design margins & architecture decision; choice of simulation models (especially intent models) for Airbus. These needs allowed to formulate an explorable concept, "Designing better tools to formally handle the external interfaces of simulation activities", which can be broken down into four exploration areas represented in Figure 8 below: these latter correspond to the four tasks which structured the annual reporting of the project.



K0. Need for tools at the external interfaces of the simulation (before and after the execution of the simulation, i.e. that will manage the inputs and outputs of the simulation)

Need 1. Tools to sollicit the simulation (i.e. inputs to the simulation) *(automotive)*

Need 2. Tools to design intent models, which are the first expression of what is intended to be simulated *(automotive and aerospace, but a slighly different understanding of intent)*

Need 3. Models and tools that allow to integrate the notion of margins and uncertainty in simulation models and visualize them in the simulation results

Need 4. User interface to visualise the simulation results and play with the scenario parameters (output of the simulation result) *(automotive and aerospace)*

Figure 8. Industrial needs in terms of tools in the K-space and associated exploration areas in the C-space

The second phase of the project consisted in exploring these four areas: it turns out to be a structured process allowing to build a clear common lock and bring out a new scientific discipline that needs to be structured.

• ***Phase 2: exploration of concepts and production of new knowledge: construction of a common lock and a new discipline (model 3)***

Figure 9 illustrates (partially) the exploration of the four concepts associated with industrial needs, and the new knowledge that was generated through this exploration.

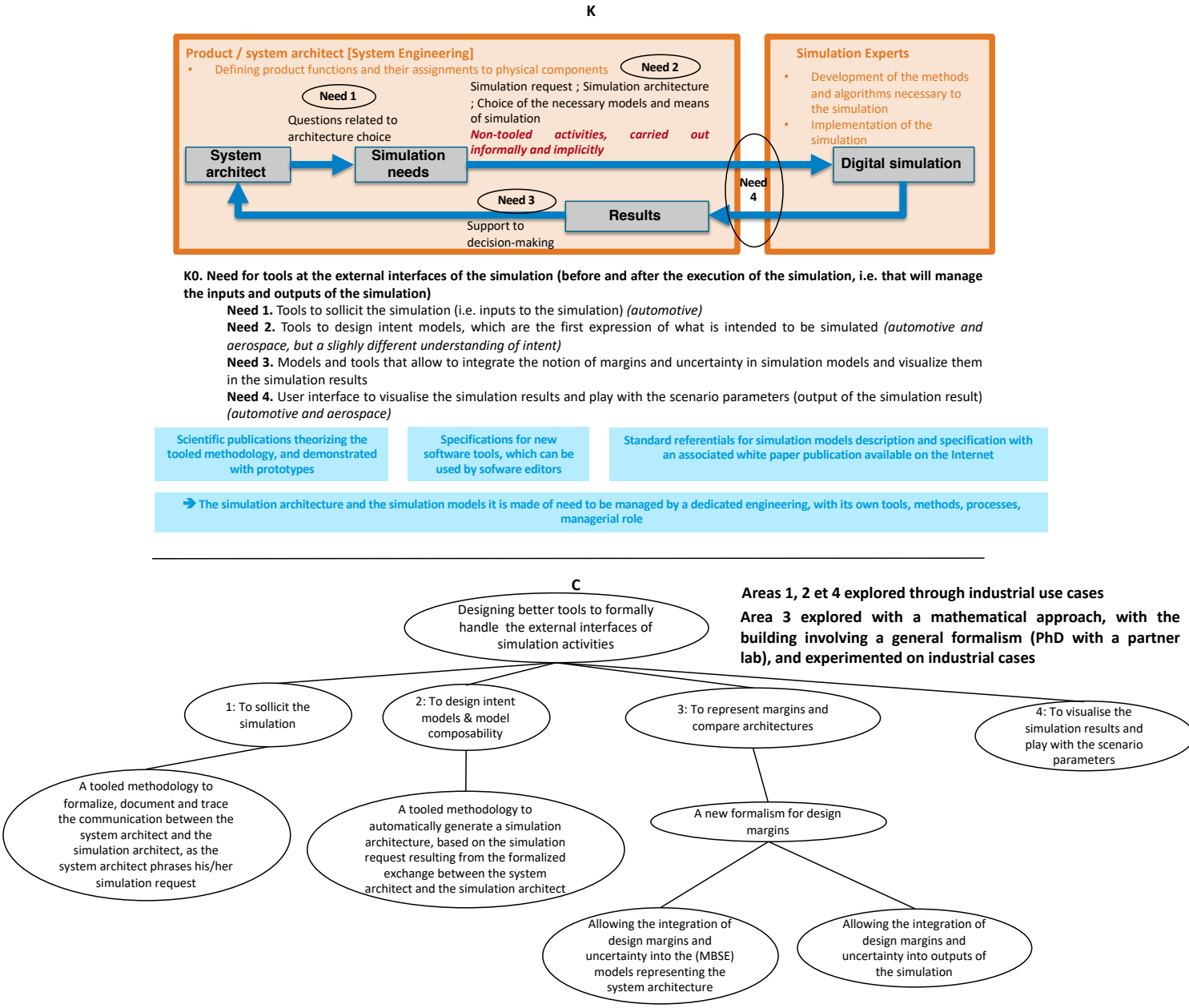


Figure 9. Exploration of the four concepts associated with industrial needs in terms of tools, and associated knowledge generation

The explorations did not seek to develop successful solutions of specific tools addressing directly the need of the industrial partners. The objective was to develop general formalisms or generic methodologies that would describe subparts of 'the process of the middle'. But it is that development of demonstrators or prototypes of tools, supposed to be illustrations of these generic methodologies or formalism, which gave direction to the building of these latter. These explorations allowed to generate several bricks of new knowledge, of various nature:

- specifications of tools which can be used by software editors; (industrial impact)
- standard referential (industrial impacts)
- scientific publications theorizing the generic methodologies and formalisms (and illustrated with the demonstration / prototyping)

- the finding that the simulation architecture and the simulation models it is made of need to be managed by a dedicated engineering, with its own tools, methods, processes, managerial role

With this last new knowledge, "the engineering of the simulation architecture" emerges as a new scientific / technological discipline in its own right, that needs to be structured. And this new knowledge allows to eventually reformulate the initially unclear concept (building the process of the middle) into an explorable concept: "C0: Design the design engineering of the simulation architecture, which will provide a generic methodology and tools", which can be seen as a lock common, of interest to the different actors, both scientific and industrial partners, and SystemX. The different exploration areas turned out to be reformulated and re-organized as exploration areas around this lock: Figure 10 below illustrates this.

• Phase 3: a common lock, and design space restructuring around this lock, and organizing the forms of rebound

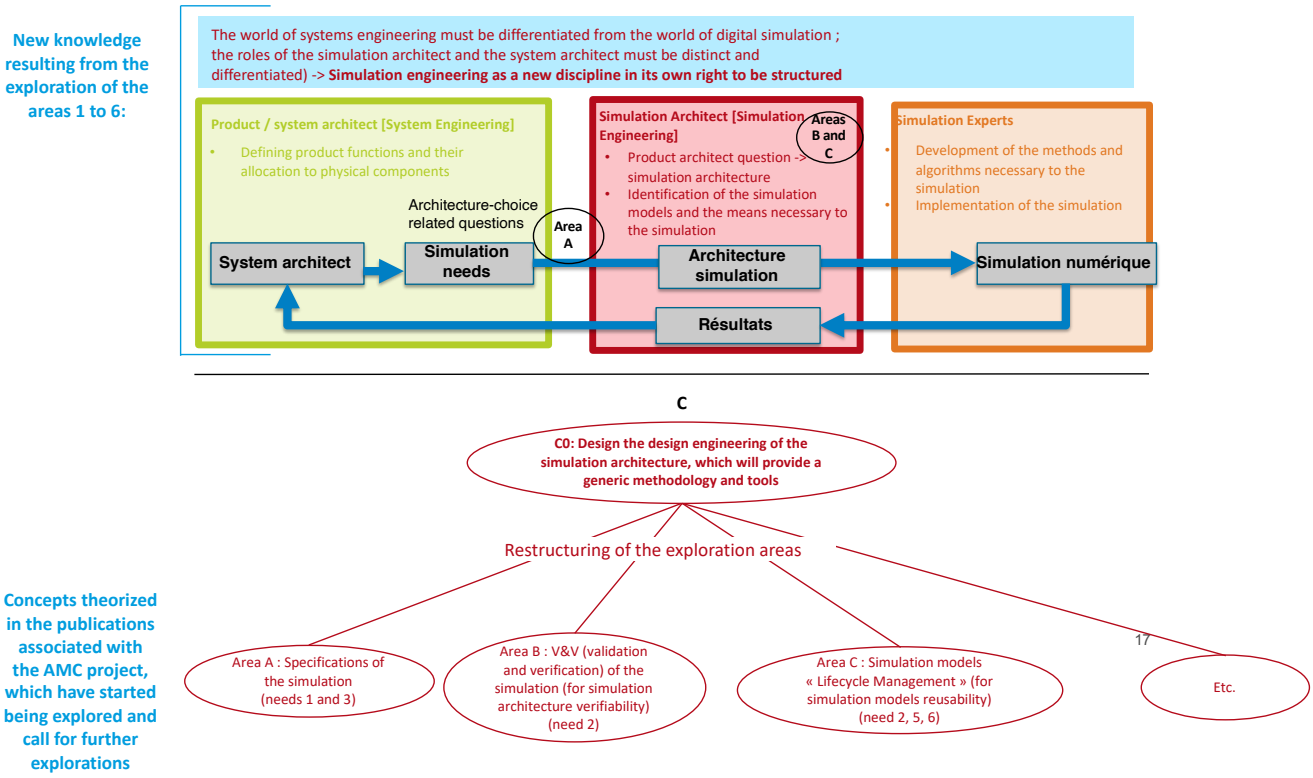


Figure 10. design space restructuring around the newly built common lock

Several forms of follow-up falling into the different RTO action models can then be considered to pursue the exploration of the design space that the AMC project has started structuring: generic specifications for simulation architect's tools (model 0); a new use-case driven project, that will continue the structuring of Simulation Engineering as a new discipline (model 1) ; scientific explorations phrasing and addressing research questions associated with the engineering design of the simulation architecture (model 2) could be considered.

In summary, the C-K analysis of the AMC project made visible the process of formulating a common lock and the process of emergence of a new discipline, that is a process of exploration of a double unknown. It highlighted that the formulation of the common lock is not an identification, but a progressive and methodical construction process (gathering of knowledge; explorations; generation of new knowledge). It also highlighted that the new disciplines to be

structured are not identified either, but are the result of a progressive and methodical construction process. The structuring of these disciplines, which was initiated during the project, opens the way to a variety of forms of rebound, which may fall under the four models of action, and illustrate the extent to which SystemX is required to simultaneously carry out and manage various forms of activities, that involve various degrees of unknown.

5. Conclusion

5.1 Summary of the findings

The first investigations reported in this paper tend to support the hypothesis according to which SystemX is a double impact RTO.
Firstly, they have revealed that through the four action models, SystemX organizes several distinct forms of science-industry relations, and articulates them. Secondly, the analysis of the AMC project illustrates that in terms of activities, the implementation of these different science-industry relationships (through the different models and their articulation) requires methodical and progressive processes of gathering, structuring and creating knowledge.

5.2 Discussion, further research and limits

The results show that the field of situations manageable by an RTO can include situations in the unknown, beyond the 'modest uncertainty' situations described in the literature. This contributes to the literature that has already identified innovation intermediaries which manage the unknown (Agogué et al., 2017 ; Agogué et al., 2012). This also contributes to the literature on RTOs: these results regarding 'double impact RTOs' are in line with previous works (Gulbrandsen, 2011) which point out that, provided they find a 'well-functioning point' (which is not trivial), RTOs represent interesting collective (gathering expertise, etc.) to handle to contemporary challenges.

The results in this paper could be seen as first insights regarding the conditions that need to be met in order to find the well-functioning point / the conditions that need to be met to be a double impact RTO.

This variety and the articulation of activities involving the exploration of unknowns of different degree and nature concerns SystemX individual projects (as illustrated by the AMC project), but also the whole portfolio of SystemX projects (and associated activities). This invites to consider the tools and managerial indicators that could support, guide and coordinate these various unknown exploration activities. Regarding limits, analyzing additional SystemX projects would provide us further insights regarding the nature of the activities it conducts.

Acknowledgment : This research work was carried out as part of the research program of the Technological Research Institute SystemX, that is supported with public funding within the scope of the "France 2030" program.

References

Agogué, M., Yström, A., and Le Masson, P. (2013). « Rethinking the role of intermediaries as an architect of collective exploration and creation of knowledge in open innovation. » International Journal of Innovation Management, 17, (2), p. 24.

Agogué, M., Berthet, E., Fredberg, T., Le Masson, P., Segrestin, B., Stoetzel, M., Wiener, M., and Yström, A. (2017). « Explicating the role of innovation intermediaries in the « unknown »: a contingency approach. » Journal of Strategy and Management, 10, (1), pp. 19-39.

Albors-Garrigos, J., Zabaleta, N., & Ganzarain, J. (2010). New R&D management paradigms: rethinking research and technology organizations strategies in regions. R&D Management, 40(5), 435-454.

Albors-Garrigós, J., Rincon-Diaz, C. A., & Igartua-Lopez, J. I. (2014). Research technology organisations as leaders of R&D collaboration with SMEs: role, barriers and facilitators. Technology Analysis & Strategic Management, 26(1), 37-53.

Arnold, E., Rush, H., Bessant, J., & Hobday, M. (1998). Strategic planning in research and technology institutes. R&D Management, 28(2), 89-100.

Arnold, E., Brown, N., Eriksson, A., Jansson, T., Muscio, A., Nählinder, J., & Zaman, R. (2007). The role of industrial research institutes in the national innovation system. Stockholm: VINNOVA.

Arnold, E., Clark, J., & Jávorka, Z. (2010). Impacts of European RTOs. A Study of Social and Economic Impacts of Research and Technology Organisations. A Report to EARTO. Technopolis Group Ltd.

Aström, T., Eriksson, M. L., & Arnold, E. (2008). International comparison of five institute systems. Denmark: Forsknings-og Innovationsstyrelsen, Copenhagen.

Barlatier, P., Giannopoulou, E. & Pénin, J. (2016). Les intermédiaires de l'innovation ouverte entre gestion de l'information et gestion des connaissances : le cas de la valorisation de la recherche publique. Innovations, 49, 55-77.

Barge-Gil, A., & Modrego, A. (2011). The impact of research and technology organizations on firm competitiveness. Measurement and determinants. The Journal of Technology Transfer, 36(1), 61-83.

Gassmann, O., Daiber, M., & Enkel, E. (2011). The role of intermediaries in cross-industry innovation processes. R&d Management, 41(5), 457-469.

Gillier, T., Osman Kazakci, A. and Piat, G. (2012), "The generation of common purpose in innovation partnerships: A design perspective", European Journal of Innovation Management, Vol. 15 No. 3, pp. 372–392.

Kokshagina, O., Le Masson, P., & Bories, F. (2017). Fast-connecting search practices: On the role of open innovation intermediary to accelerate the absorptive capacity. Technological Forecasting and Social Change, 120, 232-239.

Readman, J., Bessant, J., Neely, A., & Twigg, D. (2018). Positioning UK research and technology organizations as outward-facing technology-bases. R&D Management, 48(1), 109-120.

Perkmann, M., Walsh, K. (2007), University-Industry Relationships and Open Innovation : Towards a Research Agenda, International Journal of Management Reviews, 9(4), 259-280.

Plantec, Q., Le Masson, P., & Weil, B. (2019, June). The role of participating in user-driven research projects on scholar's academic performances: a model through CK design theory. In EURAM Conference.

Plantec, Q. (2021). Couplages science - industrie à double impact : modélisation et tests empiriques.

Santamarìa, L., Barge-Gil, A., & Nieto, M. J. (2009). Is there innovation beyond R&D? The role played by other innovation activities. Universia Business Review, 22, 102–117.

Sieg, J. H., Wallin, M. W., & Von Krogh, G. (2010). Managerial challenges in open innovation: a study of innovation intermediation in the chemical industry. R&D Management, 40(3), 281-291.

Villani, E., Rasmussen, E., & Grimaldi, R. (2017). How intermediary organizations facilitate university–industry technology transfer: A proximity approach. Technological forecasting and social change, 114, 86-102.