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► To cite this version:

Mayssa Chebbi, Vincent Chapurlat, Jean-Samuel Wienin, Laurent Aprin, Philippe Girones. A proposal for system of systems organization and governance: application to a Depollution Network. SoSe 2023 - 18th Annual System of Systems Engineering Conference, Jun 2023, Lille, France. pp.1-7, 10.1109/SoSE59841.2023.10178566 . hal-04166651

HAL Id: hal-04166651

<https://imt-mines-ales.hal.science/hal-04166651>

Submitted on 4 Jun 2024

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A proposal for system of systems organization and governance: application to a Depollution Network

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Abstract - This paper examines a network of companies responsible for depollution and dismantling projects of industrial sites, which is considered here as a system of systems (SoS) due to various factors. The challenge addressed in this paper pertains to the development and implementation of effective governance for this complex SoS. Governance, in this context, refers to the comprehensive set of rules, policies, and criteria that organize and drive decision-making processes to achieve the Depollution Network's missions and objectives. The proposed organizational and governance model is inspired by the principles underlying both system of systems management and business modelling. These principles are tailored specifically to the unique context of a business network engaged in depollution and dismantling efforts. By integrating these perspectives, this paper aims to offer a more relevant and robust approach to governing Depollution Network (DN) in order to enhance efficiency and overall performance.

Keywords - *Depollution system, Governance, Organization, System of systems, Virtual enterprise, Extended enterprise, Modelling*

I. INTRODUCTION

For several years now, the depollution and dismantling of industrial sites and wastelands has become a major challenge in view of societal, regulatory and economic expectations. Depollution projects to restore these sites to a state that allows them to be reused are by definition long, costly, multidisciplinary and multi-stakeholder [1]. Finally, they obviously have to meet various safety, security and performance requirements imposed by the inherent risks linked, for example, to the type of pollutant, the nature and current state of the pollution, the types of soil and sites to be cleaned up, etc. The work undertaken and presented in a previous article [2] has made it possible to develop a method for moving towards a form of industrialisation of depollution and dismantling industrial sites. It aims to conceptualise and then operationalise the preparation of projects, possibly to be carried out simultaneously, validation as early as possible, management and traceability by encouraging the reuse of past data and experience. This method is based on strong systemic principles, on the scope and strength of modelling, and on the processes and concepts of Systems Engineering. For example, it highlights the interest of the notion

of system of systems to model a depollution system, its organisation, expected behaviours and functions, requirements, etc. It then proposes an operational approach and tools for carrying out this modelling, verifying and validating it, and then managing a set of depollution projects carried out in a collaborative manner by a group of companies working together and sharing their resources. Each project has its own objectives, rules and means. However, they are carried out jointly by the accepted and profitable contribution of a group of companies duly identified and pooling their resources (human and technical means, applications and data), their methodologies and their techniques. In fact, to establish effective depollution systems, a network of companies is required. This network should possess a well-defined strategy, both in terms of its organization and governance, as well as in the interactions between its components. These components ought to be capable of evolving dynamically and independently of one another, in accordance with their individual strategies and objectives. This paper presents a conceptual contribution to the model of organization and governance of a Depollution Network (DN), designed to outline, validate, initiate, and manage depollution projects. This theoretical proposition is yet to be evaluated and is intended to be applicable to a variety of projects, partners, pollutants, or sites. This model aims to provide a flexible and scalable approach to depollution efforts, facilitating the alignment of diverse stakeholders while addressing different types of environmental challenges. However, its practical applicability and effectiveness still need to be tested and further refined in the future.

The remainder of the paper is organized as follows. Section II will introduce the concept of DN and outline various challenges identified through a literature review, illustrating the difficulty and complexity of achieving effective governance. Section III presents the adopted strategy for developing an efficient governance model for a DN by explaining how inspiration was drawn from virtual and extended enterprise organizations. This section also covers the development of a governance process cartography to guide stakeholders and the establishment of a Holacracy structure among the components. The final section discusses the results and outlines future perspectives.

II. ISSUES

A. Positioning: a Depollution Network (DN)

[2] presented the fundamentals of the method mentioned above, insisting more particularly on the notion of depollution projects, then called Depollution Systems (DS), whose behaviour, functions and components allow them to be considered as systems of systems. A Depollution Network (DN) is therefore formalised here as the upper-system of several DS i.e. the system in which various DS are specified then operated. DN is an organised and structured set of companies wishing to collaborate and share common values in total and harmonious consultation, in charge of preparing, executing, closing and tracing different DS carried out possibly in parallel or in complementarity with each other. DN aims to industrialise the depollution that is still often considered as artisanal or seen on a case-by-case basis. As it stands, the main objective of any DN is to ensure multi-partner collaboration, with partners wishing to remain within their areas of expertise, knowledge, and practices. This objective includes ensuring profitability for each partner, respecting safety and security expectations, adhering to environmental and regulatory rules, and tracing and providing verifiable deliverables that attest to the achievement of all objectives. Lastly, the DN enables the confirmation of handovers for industrial sites in a transitional state that meets the expectations of the involved components. Its components are thus partner companies with capacities (technical, organisational, financial, R&D, etc.) deemed relevant to the current or future needs of DSs. Depending on the project, the type of pollutant or the complexity of the site, these companies are called upon to become involved in preparing, executing, closing, organising, steering and/or tracing depollution projects.

B. Challenges

However, depollution is a field where numerous and diverse complexity factors and challenges exist [3]. These include, but are not limited to: multiple stakeholders with potential conflicts of interest, various types of pollution and infrastructure conditions, unpredictable events, simultaneous use and mastery of multiple depollution techniques within a single project, high financial and resource demands, complexity technologies and methods, constantly evolving legislation, and the demonstrated need for regular monitoring and risk assessment throughout the duration of all projects [4], [5].

The potential impacts are numerous and include: delays in project completion (e.g. due to errors in planning, coordination, budgeting, decision making, or mismanagement of human resources), uncertain control of costs and budget overruns, lack of stakeholder engagement and participation, and unsatisfactory environmental impact at the end of projects [6], [7].

To effectively organize and manage the DN over time, with the goal of concurrently executing numerous DSs, it is crucial to acknowledge that the DN constitutes a system of systems. Achieving successful governance necessitates considering two core characteristics that underpin such a system of systems[8], [9].

- **Operational independence:** Operational and managerial independence is an essential characteristic of the components of DN (i.e. the partner companies and organisations or members of the DN). Each component operates autonomously, with its own set of rules, objectives, priorities and operational controls [10]. As a result, communication and collaboration between these components can be limited, making it difficult to make joint decisions and solve problems effectively;

- **Evolutionary development:** the arrival or departure of components over time for various reasons necessarily impacts on the capabilities of the DN [11]. The integration of new components can effectively expand and enrich the range of capabilities and resources of the DN. However, it poses significant challenges in terms of interoperability and security. Conversely, the removal of a component will create gaps in the chain of skills, services, coordination of activities and interactions with other components.

Upon examining these challenges, it becomes evident that organizing and governing a DN is not an easy task. Decision-makers must find a balance between maintaining the inherent operational independence of each component and coordinating these components to accomplish the objectives of the DN. They should be capable of swiftly modifying and adapting the organization and governance of the DN in a responsive manner to optimize its performance (e.g., reevaluating the rules and protocols for interaction, communication, and collective decision-making). Ultimately, this must be achieved using necessary and relevant components that evolve independently, forming a dynamic, cohesive structure [12].

The aim of this article is to propose an organizational structure and governance model for a DN, with the goal of enhancing the design and management of depollution projects. This model will address the various challenges and complexities associated with these projects, while promoting collaboration and efficiency among the participating components.

III. MODEL FOR THE ORGANISATION AND GOVERNANCE OF A DN

The conceptualisation of this model is inspired by both the Virtual Enterprise model and the Extended Enterprise model, both from the point of view of its organisation (its architectures, its stakeholders, its components) and its management (its governance) [13].

A. Enterprise network: congruence between Extended Enterprise and Virtual Enterprise

BYRNE (1993) defines a virtual enterprise as "[...] A temporary network of independent companies - suppliers, customers, even rivals - linked by information technology to share skills, cost, and access to one another's markets. It will neither have a central office nor organization chart. It will have no hierarchy, no vertical integration" [14], [15].

The Virtual Enterprise is an organisation that brings together independent partners in a virtual collaborative network to achieve a common goal. This form of organisation allows complementary skills to be brought together to address complex projects, while reducing the costs and risks of investing in

internal resources [16]. Indeed, we have drawn from the virtual enterprise model, but our approach goes beyond and also encompasses the concept of an extended enterprise [17].

The Extended Enterprise involves collaboration between independent entities that maintain their autonomy while working together to achieve a common goal. This form of organisation creates an integrated and coherent system while allowing companies to maintain their independence.

Thus, a DN, through its organisational and governance needs, borrows characteristics from the organisation of an Extended Enterprise [18] and the functioning of a Virtual Enterprise [19] converging in fact towards an Enterprise Network, the point of balance between these two models as summarised in Figure 1 [20].

By combining the organisational principles of the virtual enterprise and the extended enterprise, it is possible to propose an efficient clearance enterprise network organisation [21].

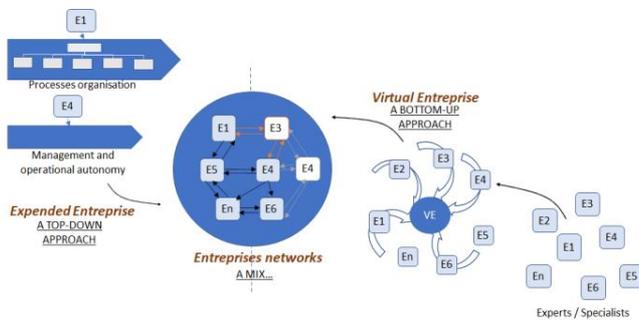


Figure 1: Crossing Extended and Virtual Enterprise models

The organisation and governance of the DN must indeed ensure the continuity of the mission of the DN and essentially, within the deliberately restricted framework of this article, address the following specific needs

- Share common objectives in the form of requirements: profitability, industrialisation, safety, security, compliance with environmental and regulatory frameworks;
- Anticipate and manage inherent risks (e.g. technical, environmental, economic, regulatory, but also conflicts between components of ownership, knowledge or know-how, market opportunities, etc.);
- Promote close collaboration of the components around this shared vision of common objectives, projects, organisation, risks involved, etc.;
- Create and maintain a climate of mutual trust and mutual recognition of the components around a recognised and proven complementarity of skills and knowledge;
- Take joint decisions and steer in a reasoned, even adapted, manner, depending on the opportunity and the specific characteristics of each project (e.g. type of pollutant, site, complexity, and requirements of the stakeholders involved, concerned or impacted by the project);
- Respect the managerial and operational independence of the components, anticipate its dynamics, evaluate its impacts and control its effects;

- Ensuring good communication between components and, in a broader sense, interoperability [22] in all exchanges of data, information, knowledge, material or energy between these components.

It should be noted that the different stakeholders involved in the projects managed by the DN, such as public authorities, non-governmental organisations or citizens, are not members of the network but are involved on a project-by-project basis as required by the engineering of these projects following a system engineering approach for example. By hypothesis, the global method from which this contribution is derived:

- Seeks to provide a holistic system view of the DN to all stakeholders, regardless of their roles and responsibilities;
- Emphasises the importance of modelling as emphasised for example in Model-Based Systems Engineering (MBSE) [23].
- Promotes a process approach commonly used to represent both the functional (static) and behavioural (dynamic) view of the DN. This type of approach is chosen here in order to ensure and assume the collaboration and coordination of the whole in order to achieve the objectives and fulfil the expected mission within the given purpose. It is, however, limited in the distribution of these roles and responsibilities to ensure the required balance between all stakeholders.

The following section outline the proposed governance model in a step-by-step manner: 1) defining the roles and responsibilities of the components in DN; 2) proposing and implementing a process cartography to effectively manage the DN; and 3) ultimately, adopting organizational methods inspired by Holacracy principles.

B. Identify roles and responsibilities

The purpose of this identification is to improve coordination and collaboration between stakeholders. The aim here is to avoid decision and responsibility silos, to prevent conflicts, to help understand the values and expectations of the members of the extended enterprise, to establish common objectives and then to set up projects that are profitable and responsible for each stakeholder.

Figure 2 summarises the vision adopted here in the form of a pyramid of responsibilities, roles and needs and thus highlights the relationships that need to be established and maintained by each partner company. This requires each of these companies to think beyond their traditional organisational boundaries. As such, this model is often used to describe the complexity of managing global supply chains, which often involve suppliers, business partners, subcontractors and other stakeholders [24].



Figure 2: Main needs and roles of DN governance as an equilibrium [24]

This level ensures the consistency and effectiveness of collaborative processes and members' roles. The Common Processes, Practices & Standards harmonise and evolve the processes of working together. The Leadership & Roles Team assigns specific responsibilities to the members to facilitate collaboration and efficiency within the network, considering the skills and needs of each project.

- Level 4: Communication and information sharing

This level deals with integrated information and communication systems that enable members to collaborate effectively. Integrated IT & Communication Systems provide tools for exchanging information, sharing business applications and working together, regardless of the geographical location of members. This infrastructure also facilitates the interoperability of business tools and promotes digital continuity within the network.

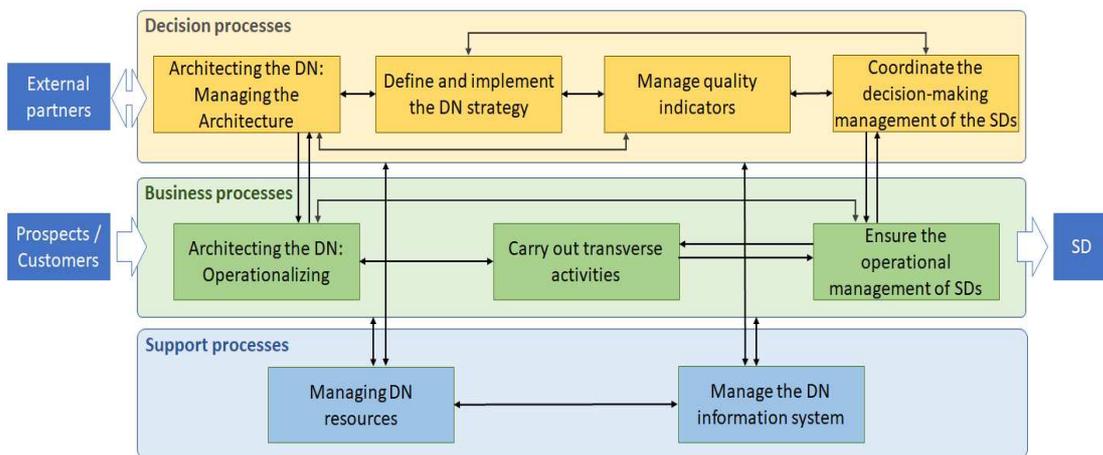


Figure 3: DN organisation and governance processes cartography

This model defines four levels which are as follows.

- Level 1: Members and responsibilities

This level identifies the different actors involved in the network and their respective roles. The Core Member Companies are the main actors, guiding strategy and projects. The Core Innovation Partners provide ideas and support R&D. Core Support Partners manage logistics and operational processes. The New Members & Associate Companies contribute to the expansion and adaptation of the network to market developments.

- Level 2: Regulation, capacity and market

This level provides a framework for collaboration between members by formalising the rules, competences and objectives of the network. The Formal Collaboration Governance Model establishes the rules of operation and communication. The Capabilities Profile highlights the skills and resources that can be shared by members. The Single Market Identity & Purpose defines the common business identity of the network.

- Level 3: Network operations

C. Towards Collaborative Process Mapping as a functional architecture of the (DN)

Several good practices, a conceptual approach and a mapping of applicable processes are proposed by the "Cadre Référentiel Ingénierie Systeme Entreprises Etendu" (CRISEE) project [25] which focused on developing a reference framework for system engineering in extended enterprises, with the aim of improving collaboration and integration between different organizations involved in complex system development. The CRISEE project also aimed to promote the use of common standards (such as ISO 15288 [26], the Nasa HdB [27]) and methodologies for system engineering, while adapting them to the specific context of an extended enterprise.

Drawing inspiration from the CRISEE project, we propose a governance cartography process for DN that aims to organize and structure its governance, as illustrated in Figure 3. Comprising three main categories of processes, this approach

offers several benefits, including enhanced communication and collaboration through clearly defined process, streamlined decision-making, efficient conflict resolution, and the promotion of continuous improvement and innovation. By providing a comprehensive overview of the governance of the DN, these processes foster increased stakeholder engagement and commitment, ultimately leading to more effective management of the network. These processes are described in the following:

Decision process

1. Architecting the DN: Managing the architecture.

- a. Validate the evolution of the DN architecture.
- b. Validate the entry of a new member or the departure of an existing member of the DN.

2. Define and implement the DN strategy.

- a. Validate the objectives of the DN: identify the business objectives and expected outcomes of the collaboration between the companies.
- b. Determine the strategy for managing and sharing common resources in the DN.
- c. Determine and validate the terms and conditions of the collaboration between the member companies of the DN.

3. Managing quality indicators.

- a. Define the quality strategy and define the quality management indicators.
- b. Develop and manage an improvement action plan for the DN.

4. Coordinating the management of the DSs.

- a. Validate the demand for any DS: validate the objective and the needs of the stakeholders and launch the preliminary study of any DS (mission and feasibility analysis, interest, etc.).
- b. Validate the DS offer: each DS offer is validated internally and then disseminated to the stakeholders, and the DS is therefore awaiting validation by the DS stakeholders, define the DS steering indicators.
- c. Authorise the launch of a DS: decision to move from a DS validated by the stakeholders to its implementation phase (execution of the DS) and the setting up of the chosen indicators.

Business processes

1. Architecting the DN: Operationalising.

- a. Prospecting for new members.
- b. Prospecting for corporate clients and organisations of the DS
- c. Assess the capabilities, shared resources and competencies of member and candidate companies.
- d. Manage the DS tender desk.

2. Ensure the operational management of the whole set of DS.

- a. DS engineering (designing and planning projects in detail).
- b. Executing a DS (adapting and executing the DS).
- c. Closing a DS (ensuring the end of the operations and tracing the REX).

3. Carrying out transverse activities.

- a. Establish internal and external communication protocols.
- b. Develop new means and resources: carry out collaborative R&D with possibly external stakeholders to move towards a common technological or organisational innovation (for related projects, related needs, etc.).
- c. Designing and carrying out specific and temporary activities, for example, to achieve a common goal for several DSs or to promote a particular outcome to potential DSs.

Support Processes

1. Managing the DN information system.

- a. Develop and maintain in operational conditions an extensive information system shared between the members of the DN.
- b. Manage the communication of the DN.
- c. Establish, trace and share feedback.
- d. Regularly evaluate indicators of performance, safety, security, etc., regarding the results of the collaboration between the companies.
- e. Deploying a DN culture and good practices: culture of security, safety, sharing, trust, etc.

2. Managing DN resources.

- a. Manage the material, human and application resources made available and shared by the member companies according to the determined resource management strategy.
- b. Managing financial resources.
- c. Training new entrants.

This processes cartography is then projected into a governance model that promotes a shared vision, accepted risk-taking and more informed, joint decision-making aligned with the objectives of the DN.

D. Governance model: contributions and proposed implementation of Holacracy

The governance approach in charge of steering the DN through the management of these processes is based on the principles of Holacracy [28]. This approach makes it possible to redistribute authority and leadership to the member companies, in order to maximise the listening and considering opinions and decision-making proposals.

Indeed, in the framework of depollution systems a hierarchical governance structure may not be suitable due to the complex and dynamic nature of the tasks involved. A circular governance structure is more fitting for a DN. In fact, the choice of a model based on Holacracy emphasizes communication, information sharing, and collective decision-making among stakeholders, who are organized in a non-hierarchical manner. The mission of each component of DN is then centred on a specific competence associated with the SoS purpose. The principle is to position the decision-making power as close as possible to the action. It is a question of assigning each mission, activity or responsibility to the most appropriate level to carry it out. To achieve this, the organization will be structured in circles, each of which has a purpose that contributes to the overall purpose while remaining

autonomous in its operation. The proposed governance model is illustrated in Figure 4, which is composed of three coordinated layers.

The first layer outlines all the roles and responsibilities, presented in a pyramid shape that does not imply a hierarchical relationship. This initial layer projects onto the DN, the second layer, where each role and responsibility are assumed by

systems, it considers the inherent complexity and challenges associated with coordinating multiple stakeholders, various depollution techniques, and variable infrastructure conditions. Inspired by principles of systems management and enterprise modelling, it provides a structured framework for decision-making. It promotes collaboration and efficiency, helping to overcome conflicts of interest and optimize resource

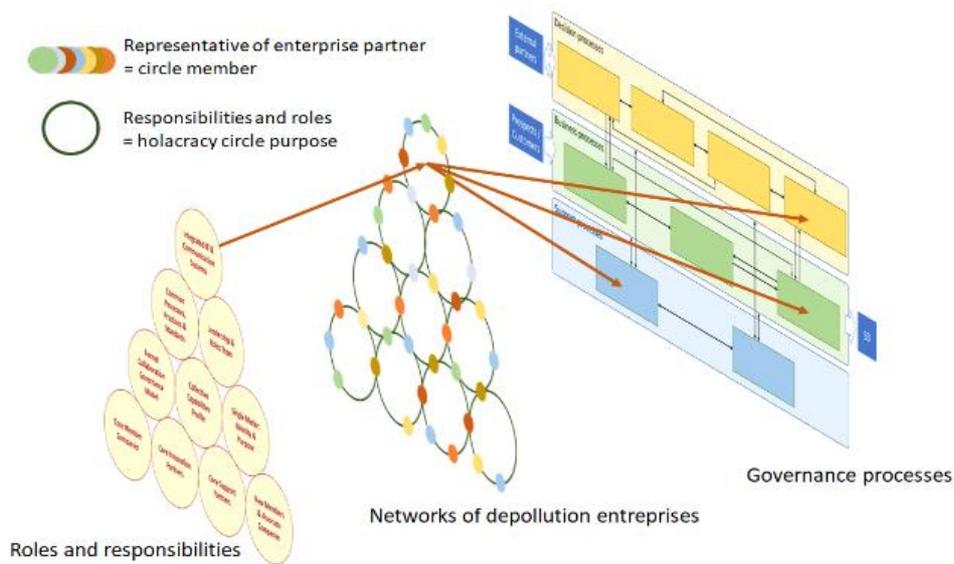


Figure 4: From Holacracy application to DN governance

representatives of the companies participating in the DN (represented by coloured dots in the figure). The companies collaborate to fulfill the required roles and responsibilities based on their competencies and position themselves within the appropriate organizational circles. These circles enable all representatives of companies partner to operate in a Holacratic manner, meaning they work autonomously while collectively coordinating to achieve common goals. Companies can participate in multiple circles, and the number of companies in each circle can vary. However, it is essential that all companies participate in the creation of the information system.

These circles then project onto the third layer of the figure, where each role and responsibility is linked to one or more processes. This arrangement indicates that each circle can contribute to the management of one or more processes.

In summary, this figure represents three coordinated perspectives of the governance model. This model allows companies to collaborate effectively and autonomously to achieve common goals. The various stakeholders work together to fulfill roles and responsibilities, according to their competencies, following a Holacratic approach.

The approach proposed in this article is well-suited to handle the specific problems related to governance in the context of industrial site decontamination and dismantling for several reasons. First and foremost, by recognizing DN as a system of

management. Scalable, it adapts to the arrival or departure of stakeholders, legislative changes, and risks. It thus ensures robust management of the challenges of industrial dismantling, by valuing collaboration, flexibility, and adaptability.

IV. CONCLUSION

In conclusion, this paper delves into the intricate topic of establishing effective governance for DN, an area marked by complexity and diverse challenges. By conducting a comprehensive literature review and investigating various aspects of the issue, the paper sheds light on the difficulties involved in achieving efficient governance. Based on Holacracy principles, this paper proposes a strategy which favours processes oriented organisation, and governance models that can be applied as a coherent projection between processes and responsibilities. Authors believe this mix of contributions can be helpful to pilot a DN and can offers significant benefits such as improved collaboration, resource optimization, and streamlined decision-making processes among the network participants.

In terms of future work, our study aims to thoroughly validate and verify the proposed approach for the governance of the DN. In order to evaluate the effectiveness and robustness of our organizational and governance model, we plan to apply it to real and diverse cases drawn from various pollution remediation and

industrial facility dismantling projects. This will allow us to analyze the model's performance in various contexts and to better understand its adaptability to the specific challenges and issues encountered in each situation. Additionally, we plan to conduct simulations to assess the model's responsiveness to unforeseen changes. Finally, we will seek to continuously improve the model by incorporating feedback from experience to adjust governance rules and policies to better align with real-world conditions.

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