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Gamification in space law: A strategy to navigate the growing landscape

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ABSTRACT

This paper presents a comprehensive assessment of the feasibility of utilizing gamification to analyze problem issues surrounding space sustainability. It examines the psychological impact of gamification on behaviour patterns and explores various approaches to game creation based on the level of abstraction. Additionally, the study investigates different types of games and their practical application in resolving space sustainability problem issues. The study introduces a system-thinking game as a tool for understanding fundamental misconceptions related to space sustainability. The law was analyzed from the perspective of the language game and the common features of law and game were pointed out. Furthermore, the study highlights the interpretive role of current space activity as a significant mechanism for law-making, drawing from recent space law and policy documents. These findings underscore the utility of gamification for reconstructing space governance and ensuring space sustainability. Building upon the insights gathered, the concept of the game is constructed based on the PARDI framework. This framework provides the context and inspiration for all interested stakeholders to collaboratively develop a meaningful and serious game. The core gamification concept, elucidated through the lens of space activity in this publication, serves as the foundation for this co-construction. In conclusion, this research demonstrates the potential of gamification as a valuable tool for analyzing and addressing space sustainability challenges. By leveraging the PARDI framework and core gamification principles, stakeholders can actively participate in the development of a game that promotes a comprehensive understanding of space governance. Through this collaborative effort, we can pave the way for a more sustainable and responsible future in space activities, ensuring the long-term viability of human activities beyond Earth's boundaries.

1. Introduction

In less than 70 years, the "evolution" of space activities has progressed from the notion of open sky to acknowledging the Kessler effect, i. e scenario in which collisions between space debris create a cascade of further collisions increasing the risk of damage to satellites and spacecraft, and the need for space traffic management and for a space circular economy [1]. In parallel, the space law has evolved from a legally binding international framework convention and a few national legislations to a wide range of guidelines, recommendation, compendiums, best practices, and 42 national legislations [2]. The landscape of space activity is still growing with numerous space actors of private, public, and mixed status, as well as space objects of uncertain status, for instance space object according to Registration convention [3], space debris with non-functionality, non-usability, non-operability or even abiotic space resource [4].

Obviously, managing all these elements within the complex matrix of relationships has become increasingly complicated, and the traditional hierarchical system of regulation, reflecting the one directional communication between rules-making authority (international or national) and legal subjects, is no longer sufficient. The Open-Ended Working Group on reducing space threats through norms, rules and principles of responsible behaviours, convened by the resolution 76/231 [5] of the United Nations (UN) General Assembly, stressed in this context: "non-binding norms, rules and principles often inform and reflect how law is interpreted and applied in practice and can help to resolve conflicting legal rules and because they are rooted in values and dependent on practice, they are subject to reinterpretation" [6]. The asymmetries between actors depend on factors such as the communication system, the means of compelling actors to fulfill promises and threats, the speed of engagement, the rationality of predictable reactions [7], the relative damage which should push actors to seek creative ways in their actions. This implies that in coming decades, space regulation will be highly dependent on how each participant in this law-making

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polylogue understands the space activity context and raise awareness among their counterparts for achieving sustainable activities. To address such kind of communication and organisational issue, it is possible to explore different solutions in an experimental context, using for instance social simulations and serious games.

Although simulation and modeling are already utilized in the form of moot courts and UN sessions addressing matters related to space activity, such as space games or mathematical simulations of space debris, the novelty of our research lies in its distinct characteristics. First, in the contrast to previous researches that predominantly discussed the procedures and outcomes of simulations [8], this article places emphasis on the initial stages of the game development. Therefore, at the core of this article lies the question, "How can tools for gamifying space governance be used ?", rather than solely focusing on the potential outcomes of the game. Second, the fundamental aspect of the proposed concept is grounded in a holistic approach that incorporates technical, physical, economic, political, and juridical aspects within a single comprehensive game, rather than proposing separate games or distinct on-orbit and legal moot phases [9]. Third, in contrast to the wide array of simulations available, this research will focus on the utilization of serious games as a distinct type of simulation and gaming concept [10].

This article brings together three research domains, and it is structured as follows. The first section is concentred on a brief description of the phenomenon of gamification as a non-linear type of comprehension and different types of the games used to date in the space domain (the psychological part). The second section aims to recognise the peculiarities of the constructions of a serious game with its inherent debriefing session (the gamification part). The third section will shed light on the theoretical basis of efficiency of the gamification of law from the perspective of their common understanding as language games (the legal part). The fourth section will illustrate the aforementioned observations by presenting examples of game constructions using the conceptual model within the PARDI (Problem, Actors, Resources, Dynamics, Interactions) modeling framework [11].

2. The phenomenon of gamification as non-linear type of comprehension

In this section, the game will be analyzed as a non-linear form of reflecting reality, focusing on its psychological aspects and impacts on the human behaviour. Psychological phenomena, such as abstraction, which form the base of the concept of non-linear system thinking, will be examined in the context of their application in the space domain.

2.1. The prerequisite of game effectiveness as a non-linear means of reflecting reality

The value of games resides in their non-linear approach to explaining reality, enabling participants to immerse themselves in complex problem systems, providing a personal experience that conveys the underlying logic of the system. This approach bypasses the need for a cumbersome sequence of details, providing a more engaging and intuitive understanding of the subject matter. Richard Duke, the founder of gaming/simulation in the 1970s, argued that humans think in images and communicate them through language, with listeners reconstructing those images using their own sequential descriptions as building blocks [12]. This perspective highlights the importance of system thinking, which focuses on the collection of interconnected elements, rather than individual parts [13].

While all systems can be analytically studied, their essence can only best understand when they approached as a whole, due to the unique features and characteristics that arise from their subsystem interdependences [14]. Meaning that the deep comprehension of a system is possible using not only analyses and synthesis - based mental operations, but also using abstraction and generalisation [15], which are the foundations of game modeling. Ultimately, the games have an impact on the human on the base of *interiorization* of the game experience into their personalities [16].

There is a lot of psychological research highlighting the limitations of our ability to comprehend reality, arguing that our mindset creates simplified map of reality to facilitate decision-making for survival purposes [17]. To handle complex problems efficiently, we often rely on automatic, primitive responses, based on abstraction and association, rather than time-consuming, fully informed decision-making [18]. This creates only a feeling of understanding, but not the awareness how the situation organized [19].

By contrast, implicit awareness shifts to explicit awareness when the world becomes abnormal or critical, prompting individuals to register these changes through personal experiences [20].Games provide a secure framework for this effect through abstraction, which plays a role in our understanding of the world. The abstraction plays an important role in our orientations in the world, but in the mind of each person they could be partial, non-objective, or simply different. The different levels of reality reflection, referred to in game literature as the "cone of abstraction" [21], aim to: 1) attract attention to the important characteristics of the problem situation; 2) depict them within the non-habitual context; and 3) reconstruct implicit awareness into explicit awareness through a careful manipulation of abstraction and their impact on our behaviour.

2.2. Cone of abstraction as a framework for different types of games

The experts in gamification explain the creation of the gaming model like multilogue between players and designers (iterative and shared process), which try to respond to the question – *How many aspects of the context need to be considered in order to better understand and resolve the problem?* The response on this question is the identification of the position on the cone of abstraction (Fig. 1), which depends on the aims we need to reach (attract the attention, learn some facts and procedures, train the skills, create new approaches or change the initial patterns and habits) and the tools used (abstract model, qualitative models, scientific quantitative models, real models) [21].

The dilemma between a detailed and a general approach (or in other words a low and hight position on the cone of abstraction) may be observed in the context of space governance. For instance, Andrieux has noted that the company "Infinite Orbits" had chosen the jurisdiction of France for its operations due to its detailed and clear technical requirements regarding the supervision of space objects under its space legislation [23]. This company provides the orbital servicing in the geostationary orbit using autonomous navigation system capable of far and near range navigation for satellite rendezvous, handle Space

Fig. 1. The concept of the Cone of Abstraction, adapted to this research on space governance [22].

Situational Awareness (SSA) and inspection missions [24]. Thus, the detailed legislation provides the company with certainty and enables technical interoperability of satellites that adhere with such legislation. By simulating the application of legislation, companies like this one can learn how to enhance their operations. However, what should be done in cases where there are insufficient requirements to guide certain space operations?

In this example the company have detailed information about the framework governing of their work, allowing them to enhance the awareness of their members and counterparties through the games that have low abstraction and incorporate more specific details. These games correspond to closed simulations with predetermined outcomes and limited autonomy for the actors involved. It should be mentioned that the simulation is widely used in the space domain in the area of SSA, for example in space debris models such as LEGEND (NASA's Orbital Debris Program Office's primary model for study of the long-term debris environment projection) or ORDEM 3.2 (the latest version of the NASA Orbital Debris Engineering Model) [25]. However such simulation is substantively broader concept than game and only be used in the context for the embodiment the reality into the games. This was illustrated in the Ariadna study, "Game Theoretic Analysis of the Space Debris Dilemma" (Ariadna ID 15/8401) in which active debris removal strategies were examined [26].

In contrast, a game based on a hight abstraction of reality is the metaphorical game. It aims to immerse professionals in another world with different rules, diverging from those of the real world [21]. An example of that type of the game is "The 22 Systems Thinking Games for Effective Communication about Climate Changes" [27]. However, they will not be the subject of this research due to their general applicability, which does not reflect the peculiarities of space governance. Between the closed simulation game and the latter lies the open policy game. This game facilitates the development of different solutions and strategies, and also provides an environment for unplanned learning objectives to emerge as the game scenario unfolds [28]. This forms the basis for a substantial number of the entertainment games around space activity, which are developed to emphasize destruction [29], assembly [30], and dodging space debris without consideration of the natural conditions of outer space (such as speed, interaction trajectory, etc.) and the legal framework surrounding these activities [31].

More interesting from the space governance perspectives, an open policy game was organised as part of the agenda of the Paris Peace Forum titled "Manoeuvring Towards Space Sustainability: Cooperative Strategies for Future Safety and Security". A challenge to resolve was addressed to the representatives of space companies, like Amazon or D-Orbit, which can be summarized as follows. There is a risk of collision between two satellites due to a cyberattack on one of them, but they are unable to communicate with each other because the algorithm controlling the SSA functionality is confidential. The participants are faced with data-sharing and emergency response challenges in the context of a lack of regulation and time limitations (3 h) [32]. This type of interactive setting (very similar to role-playing) between stakeholders differs from just having discussions about the problem due to abstraction from the real situation and from the real role of participants (for example, space enterprise plays the role of the UN). Despite of the above-mentioned game being advertised as an open policy game; a lot of details were presented aligning it more to a closed simulation game. In the following discussion, we will explore why it is possible to incorporate elements from both types of games, using the example of a game organized during the Paris Peace Forum.

First, the expertise of the participants may require a game with details elements, as even minor discrepancies in the game world could be perceived as inauthentic by the players, leading to the rejection of the game [21]. This aspect is crucial from a psychological standpoint, as the inclusion of accurate details can immerse experts in situations that align with their areas of responsibility.

Second, such misalignments are possible because the game model may consist of different cones of abstractions concerning the number of roles, data, and processes involved, with each aspect being more or less reflective of reality. Experimentation with these different cones of abstraction allows for the creation of reference systems capable of providing the necessary interactions required to simulate and address specific problems. Meanwhile, the level of realism and fidelity perceived by individual players may not directly correlate with the actual degree of abstraction within the game's conceptual system. To align the attributes of reference systems with the game world, we can incorporate the game's resources and rules through suitable levels of aggregation, depending on the time frame and target users of the game [21]. These aggregation levels begin at the individual level, progress to other actors and their interrelations, extend to the system as a whole, encompass the subsystems and aspect systems, and finally consider the environment. In addition to the option of switching 'vertically' between these levels, another strategy is to switch 'horizontally' and sequentially explore perspectives from various roles, helping participants to gain a comprehensive understanding of the big picture [22].

Thus, despite being designed with a high level of details (aggregations), this game falls into the open policy game category due to the absence of a "correct" final decision and the possibility to create interactions within the game. From this perspective, we can conclude that the cone of abstraction serves as construction set that can be combined into different forms depending on the problem to be addressed and the understanding of those involved in the game's creation.

3. Serious games, a specific type of game that carries meaning

This section will focus on serious games as a modeling approach that commonly depicts real-life systems or their elements, including their associated dynamics, in a condensed and often stylized manner. These games provide a simplified world that allows people to step back and understand the structure the real world [33]. The distinctive feature of this type of the game is that it serves only for serious purposes beyond pure entertainment value, for obtaining meaning that has three important criteria: "motivation", "relevance", and "transfer". Firstly, the game should aim to generate enthusiasm among players not only for playing the game itself, but also for the topic it addresses. Second, relevance can be seen in two ways: the connection with the purpose and what happens in the game ("internal relevance") and the connection with the purpose and the value retrieved from the game ("external relevance"). Third, "transferring" knowledge or experiences from the game environment to another setting should lead to valuable outcomes (i.e. attitude change, data collection, or exploration) [34]. This result is often reached via a debriefing process specific to serious games.

3.1. Triadic construction of serious games

The concept of triadic game design is explored in the Harteveld's research and focused on the game creation as a balancing of three contexts, described by the author as "worlds" (trilemma): reality, meaning, and play. The reality world is the manner in which the real-world situation is reflected in the game for obtaining impact with the new meaning. The challenge of this world is in finding the appropriate position on the cone of abstraction. Aspects that are part of this world concern the specific problem that needs to be addressed (for example, sustainable space activities), the factors involved (for example, exponential growth of commercial space activity as a factor causing orbital congestion and acceleration of debris mitigation initiatives, political tension as a factor blocking legally binding international regulation and the increasing growth of militarisation of space activities, society's dependency on space technologies as a factor in space sustainability initiatives etc.), their relationships (for example, society's dependency leads to initiatives enabling the better protection of critical space infrastructure, the impact of legislation on the development of sustainable technologies or limiting of commercial space activity, etc.) and

their evolutions over time (for example, space activity best practices codified into guidelines, changing practices according to challenges posed by space orbit cluttering, etc.). Criteria include flexibility, fidelity, and validity. Individuals involved in this world are subject-matter experts, and consultants (for example, operators, rocket engineers, COPUOS participants, representatives of national space agencies, space lawyers, etc). The world of meaning is concerned with the creation of value. It is related to disciplines, such as the learning sciences, psychology, and semiotics. From the perspective of psychologists and pedagogues, two elements structure player engagement: the subjective enjoyment of the game experience and the motivation to play the game [34]. Two virtues are generally attributed to the use of a serious game: engagement and learning [33]. The system in the game can be seen as a social system. It is a situation in which people interact with their values, knowledge, expectations, moods, and whatever personality characteristics they may have. This is a part that the designer cannot manipulate [35], but can observe.

For the creation of a "value proposal" such aspects are necessary: the purpose of what the game needs to achieve (for example, to understand how concerned actors will communicate while grappling with the challenges for space sustainability; which strategies they will explore in different contexts, such as changing jurisdictions, purposes of the activity, timeframes; which rules will be useful or limiting during this process; training negotiation skills within mentioned situations, etc.), the strategy of how this purpose is going to be achieved (for example, competitive or cooperative strategies for clearing space debris or the creation of the on-orbit manufacturing), the concrete operations that aim to achieve this purpose (for example, lack of the information about purpose of satellite helps to refine strategies of communication, manoeuvring in the incertitude, etc.), and the context in which the value creation needs to take place (for example, short timeframe of collision avoidance or large timeframe for the creation of a circular sustainable space economy; changing the current space governance practices or starting from scratch using a simulation of the economy deploying in the space). From this perspective, this is necessary to verify how pertinent, connected, and applicable the game is to its original purposes. It is the world of teachers, storytellers, and—depending on the purpose—other people that know how to achieve a certain value.

Between them as a mediator is situated the "Play" world: highly interactive and engaging tools that immerse people into a fictive situation. This can range from simple point-and-click adventure games, like game "Bureaucratère", which focuses on making various decisions to manage the space resources [36], to grand-scale virtual worlds with thousands of players, such as World Craft [37] or Kerbal Space Program [38], which emphasize fostering player's creativity in construction and management. This world is affiliated with disciplines such as media studies, game design, and human-computer interaction and it is related to game designers, artists, and media theorists [34].

Thus, the creation of a game that holistically reflects space sustainability governance could incorporate the following elements: 1) a conceptual map should be constructed based on the input and perspectives of a wide range of stakeholders, emphasizing a co-construction approach; 2) this conceptual map should be balanced with other worlds of game design (meaning and play) upon the expertise of learning sciences, psychology, semiotics, designers, artists, and media theorists; 3) the resulting game should be tested and refined, taking into account valuable insights and addressing biases. This iterative process of testing and rebuilding is akin to the nature of the law, where rules not only dictate player behaviour but also shape the space of the opportunities for change.

3.2. Debriefing

The debriefing is the most important phase of the serious game because it provides the results for which the game was created. During this phase, participants engage in abstract conceptualisation, comparing and evaluating the significance of their game experience in relation to existing theories and real-life situations. This process allows them to deepen their understanding of the simulated situation and propose changes based on the knowledge gained. These proposed changes are tested within the game before considering their implementation in the real world [28].

There are different modes of conducting the debriefing process, such as oral discussion, written reflections, or fast games [39]. Regardless of the mode chosen, the debriefing serves as a means to transform the game experience into new knowledge through the use of questions [40], so there are different approaches to the construction of a typical set of questions for the debriefing process. For example, Meadows suggests: (1) What happened in the game? (2) Do these features characterise real life? (3) Which characteristics of the game created these features? (4) Do these characteristics exist in real life? (5) How should the game be changed to obtain better results? (6) What could be the obstacle in real life preventing these changes? (7) How should actions for the changes be developed? [27]. De Wijse-van Heeswijk put forth another proposition: (1) What went well? (2) What could be improved? (3) What do you need from yourself and others to improve? [41] On the base of both variations the transference of game experience to real world situations with the emphasis on the limits and possibilities become possible.

Considering the aforementioned points, the following questions could be proposed for debriefing in the context of a serious game focused on space sustainability law: 1) How do the peculiarities of national legislation and culture relevant to the actors make an impact on the different interactions relevant to the space activity? 2) Which mechanism of the handling the threat is more applicable for players: indirect (engaging via international institutions) or direct (engaging directly between operators and administrators)? Which indicators influence the choice of one or the other (time, respect, certainty, etc.); 3) Which strategies do the players use for resolving the dilemma of personal and common interests within the space activity? How does each factor relevant to these interests (financial, security, technological, cultural, legal) change the balance achieved by each strategy? 4) What psychological difficulties do players face? 5) How should rules be changed to resolve the revealed challenges and enable sustainable space activity through a common understanding of all players? etc.

4. The space law as a "language game"

In this section, the shared characteristics of law and games are explored, and the intersections of gamification with important concepts in the law-making process, such as adaptive governance and the veil of ignorance is examined. The first concept, adaptive governance, is selected due to its dynamic character and dependence on the comprehension of values by the participants of changing situation and the second concept, veil of ignorance, is chosen specifically for its ability to address the uncertainty that decision makers often face. Both key characteristics are related to game features, that is why they are decided to be analyzed in correlation. In the end of this section, the increasing interpretative nature of current space governance sources was presented as an argument to support the effectiveness of gamification in space law for promoting sustainable space activity.

4.1. Common features of law and games

The understanding of legal values has historically revolved around two distinct paradigms: positive law, which places emphasis on the textual nature of law, and natural law, which is grounded in moral principles [42]. Such paradigms have undergone convergence in the context of the growing the role of interpretation. Under the post-modernist paradigm, the law, as a one of the types of knowledge about social interactions, is an instrument of specific semantic narratives that is conditioned by a specific historical, cultural, and political context [43]. The choice of certain compositional possibilities in the

construction of legal norms can give information about a legislator's way of thinking, outlook, skills, i.e., the characteristics of the sender of the linguistic messages and its functions (cognitively, motivationally, and behaviourally). In this regard, the law is one of a linguistic abstractive reflection of the humans' interactions.

Such a point of view leads to 'double reading'. The first reading constitutes stability, confirms the status quo, and reaffirms the dominant interpretations (closer to the positivism paradigm). The second reading is an attempt to deconstruct the existing world (so called language games, i.e., models, means of rational reconstruction of the functions of language or of the relations between language and reality) [43]. Therefore, even through the prism of the language, law cannot be recognised just as a text, or a linear form of explanation (with obvious entry point and introducing itself word by word until it comes to an end). The development of law is an interactive process of co-construction of the rules taking into consideration different aspects of the complex system of the regulation – a non-linear form that explains complex systems through engaging with the experience of abstractive models' functioning. It takes into consideration not only individual components, but also their interconnections that create a context for defining and solving complex problems (system thinking [27] or gestalt communication mode [12]). Law students may remember their first feelings of interacting with the complexity of law when determining jurisdiction, selection of the most appropriate set of rules from the entire body of legislation to resolve a particular case when faced with different interpretations. The discomfort an inexperienced person is confronted with a real complex system is termed *system or game vertigo.* [44] Each of us struggles with this feeling when we attempt to resolve a problem without a sufficient comprehension of its nature.

Interestingly, the research of Venzke has concentrated on the metaphor of the language of international law and combining it with an analogy between the interpretation and the playing of games. He recognises law as a language from 2 perspectives: First, dualism of background (text of law) and execution. From this point of view, execution of law is similar to the game of chess where each move on the chessboard changes the state of the game, and it affects later moves, but does not affect the rules of the game. Second, monism of the background scheme (text of law) and its execution. From this point of view, international law is a game, rules of which go along according to the path of the game, so it is a game without end.

Thus, Venzke argued that the enforcement of international law is a triune process combined with: 1) law as a common general context ensuring that intentions can be revealed (traditions emanated from historical practices are underlying it) Nevertheless, that context provides common context, it could be the obstacle for the creativity of reconstruction of social interactions. For example, participants' previous experience in using simulators (closed simulation games) might have a confounding effect [45]; 2) interpretation due to different intents; 3) interaction of participants in an interpretative community [46]. This concept brings us to a triadic game design that consists of Reality, Meaning, and Play [34].

By considering the law as a language, we can identify certain similarities with games.

- Both law and games serve as non-linear representations of real-life situations, abstracting complex concepts/systems into smaller models or prototypes.
- Law and game are characterized by a flexible system of rules that not only dictate player behaviour but also define the range of opportunities for potential changes.
- The foundation of law, as a language game, lies in the contextual framework shaped by the players' modes of thinking and the underlying social architecture [47].
- Validity in both law and games can be assessed through two approaches: either by adhering to their rules or by challenging them, testing how participants' interactions change in response to alterations in the rules.

4.2. How gamification correlates with concepts of governance

Adaptive governance, as a concept from institutional theory evolution of institutions for the management of shared assets, has been suggested to apply to space resource governance [48]. This refers to the evolution of the rules and norms that promote the satisfaction of underlying human needs and preferences given changes in understanding, objectives, and the social, economic and environmental context. The pivotal point is that the normative criteria used to judge whether a change in governance arrangements is 'adaptive' or 'good' is derived from *values and preferences*.

According to the widely used gamification theory of Argyris and Schön [49], the complexity of a problem (for example, ensuring space sustainability) confounds our mental map and pushes us to search for another strategy that will address and work within the governing variables (for example, change of national legislations, adoption of numerous recommendations on the basis of the Outer Space Treaty). However, we have the opportunity to bring about significant changes by subjecting the governing variables to critical scrutiny (for example, to change space governance mechanisms from the recognition of space as an operational environment to the subject of legal relationships with an interest to be protected from degradative human activity). Where something goes wrong, it is suggested, an initial port of call for many people is to look for another strategy that will address and work within the governing variables, adapting to environmental changes through action (single-loop learning). To obtain this level of depth of knowledge a closed simulation game will be more appropriate [50]. An alternative response is to question the governing variables themselves, to subject them to critical scrutiny that leads to an alteration in the governing variables, and thus, a shift in the way in which strategies and consequences are framed (double-loop learning) [49]. From this perspective, we may suggest using open policy games with a high level of abstraction. Depending on the forms, such as closed simulation game or open policy game, the serious game can serve as a powerful tool for acquiring in-depth knowledge by identifying and rectifying behaviours that do not align with changed situation or values of the participants. Thus, the game can be regarded as an instrument for facilitating adaptive governance.

Rawl's concept of the veil of ignorance has the aim to nullify the effects of specific contingencies which put men at odds and tempt them to exploit social and natural circumstances to their own advantage. To achieve this, the parties should not know how the various alternatives will affect their own particular case, and they are obliged to evaluate principles solely based on general considerations [51]. This is possible to realize by the placing decision-makers under a constraint of ignorance about their own identities and attributes. Although the decisionmakers know or can guess whether they will occupy position, the rule introduces uncertainty about whether they will reap greater gains from the decision [52].

Both possibilities could be realised through gamification. The first is possible thanks to the highest level of abstraction from the real situation (so called metaphor game). The metaphor serves to put professionals in another world with different rules instead of the rules of the real world because people are going to take their experience from the real world to the game and try to simulate what they know, instead of looking at the process which happening in the game. It leaves place for players' imagination and agency during the game, which could be clarified against real problems during debriefing. The second is feasible through the mechanism of changing the roles of the players, where, for example, a representative of government will be obliged to occupy the role of a private operator or vice versa. To map the attributes of reference systems to the game world, we may implement into the game design resources and rules of the game appropriate levels of aggregation based on the

timeframe and target [21]. From this perspective, the game could fulfil the role of a veil of ignorance for space governance and change roles for better communication between space actors with different statuses, nationalities, cultures, etc.

4.3. Enhancing the role of games in space governance through increased emphasis on interpretation

The vast body of space law currently serves as a framework of best practices, and their effectiveness can be ensured through their widespread acknowledgment and acceptance. This paradigm is different according to their flexibility, co-constructability, willingness of actors and finding common ground in the dangerous situation. Let us examine some concrete examples.

First, this paradigm is apparent in issues of space security. The Open-Ended Working Group on reducing space threats through norms, rules, and principles of responsible behaviours noted that it is important to emphasize the identification of positive behaviours that make operators in outer space feel safe, secure, and confident in the intentions of others. Non-binding norms, rules and principles often inform and reflect how law is interpreted and applied in practice and can help to resolve conflicting legal rules. Because they are rooted in values and are dependent on practice, they are subject to *reinterpretation*. General commitments create room for interpretive differences and loopholes, such as the meaning of "long-lived" debris, or of "due regard". Vague principles might also deter agreement by States. For example, the lack of clarity surrounding the definition and identification of "space weapons" is a long-standing obstacle to agreement on arms control measures in space [53]. A similar idea was proclaimed in the regional strategic document, most notably the European Union Space Strategy for Security and Defence: "Since most space technologies are dual use, what constitutes a space threat cannot be identified by observing space objects, technologies or space capabilities in isolation, but by taking into account behaviour. Assessing space threats requires a comprehensive analysis of capabilities and related behaviours in orbit, on the ground and in the cyber domain based on a thorough understanding of counter space capabilities" [54].

Second, even the issues not directly correlated with security adopt the same approach to space governance. More frequently in documents we may see expressions such as 'framework for the global governance of outer space activities, consistent with international law'. For instance, in the "Space2030" Agenda, States encourage the Committee to continue to coordinate efforts, to strengthen the implementation of the UN treaties and principles on outer space and to complement existing international space law, and when appropriate, to respond to emerging issues [55]. One form of this implementation could be found in the Artemis Accords. Frans von der Dunk argues that the intention of the United States is to gather consensus around its interpretation of the Outer Space Treaty regarding the exploitation of the Moon's resources [56]. The mandate of the Working Group on Legal Aspects of Space Resource Activities also reflects the interpretative and dynamic nature of space governance that changes the paradigm of the legally binding regulations [57].

Thus, interpretation of the application of the 5 legally binding international space treaties remains the core of international and national space law, but according to the changing context, actors will depart further from the literal readings of these treaties. On the basis of this statement, the following characteristics of space governance creation may be highlighted.

1) less abstraction: law enforcement is closer and more dependent on current practice;
2) flexibility: the same abstractive norms in situations with different peculiarities may be changed;
3) dynamism: the interpretation of norms changes not only according to differences in space (in the broad meaning), but also in time;
4) multilogue application changes unidirectional legally binding norms (multilogue is the primary interaction pattern in a gaming/simulation for transmitting the holistic thoughts (gestalt), which is a structure or configuration of physical, biological or psychological phenomena, so integrated as to constitute a functional unit with properties not derivable from its parts of communication.); and
5) the emphasis is not on the linear comprehension of binding norms, but on the non-linear interpretation of the law according to the changed context.

To conclude this section, the serious game which we intend to develop aims to achieve the following purposes at a minimum.

- learn the legal and policy framework to ameliorate communication issues;
- find the limits of law and test new best practices to resolve problems;
- mitigate misunderstanding within uncertain communication parameters, through the creation of typical algorithms of behaviour in cases with various variables;
- develop mediation skills and eliminate cognitive bias caused by emotionality and lack of clear communication; and
- develop the ability to quickly and accurately assess risks.

5. The PARDI model of the holistic serious game on space sustainability

As a result of peeking behind the scenes of the creation of serious games, this section demonstrates how core elements of gamification could be used for the reconstruction of a potentially harmful situation regarding space sustainability, depicting the obstacles, resources, and other conditions as a mental map that immerse the reader into technical, physical, economic, political, and juridical interdependent relationships.

The PARDI (Problem, Actors, Resources, Dynamics, Interactions) framework consists in a series of participatory workshops designed to collectively envision a future open and dynamic management system. The aim is to create a system that is adaptable, anticipatory, and capable of effectively addressing the conservation of natural resources and the promotion of sustainable development. This framework brings together diverse stakeholders in a partnership to examine these issues and collaboratively generate solutions [11]. The originality of this framework lies in the co-construction of a shared "conceptual model" of the relationships and functioning of the different aspects of a particular context or territory. Therefore, our research proposes the adoption of a holistic gamification paradigm to address challenges in space activities. It also extends an *open call* to all stakeholders who are reading this article to utilize the elements outlined above and contribute to the collaborative development of a serious game focused on space sustainability.

As a mental model it has a *high level of abstraction* combined with the developed aggregation of game elements. The abstractness of this system thinking model is seen in the pointing out of relationships and their elements (actors, resources, dynamics, interactions) according to the common general structure, rejecting the peculiarities of each national legislation, technical regulation and best practices of each operator, and the policy of each space agency, etc. At the same time the actors are outlined according to their interests, including governance, control, possession of property rights, and mediation. They are all divided into two types: the main actors (space agencies, operators, mediators, affected actors) due to their direct participation in the situation in space, and complementary actors (proprietors, beneficiaries, insurers) due to their ability to influence the decisions of the main players. The actors make decisions using different types of (inter)actions as communication, manoeuvring, lobbying for the preservation of property, services, and incomes, taking into consideration available resources, including expenditures (non-renewable energy, fuel, etc.), compliance with common rules and procedures and consent to comply with any rules requested by

other parties (the list of rules will be accessible to each participant). This game could be played according to different time framed strategies: immediately risk elimination, simulation of current procedures for mitigation of harm, or event testing of innovative approaches as an on-orbit manufacturer, or a wide variety of active debris removal actions (*the world of play in the triadic concept*).

The general framework consists of such essential elements: informing; consultations; supervision and control; financial guaranties for liability; lobbying of financially interested actors and potentially affected actors in decision-making about saving the satellite; tackling the environmental consequences, etc. All actors could be engaged in different dynamic combinations of actions: the capability to manoeuvre satellites or to control the satellite, to communicate; the possibility to identify the satellite; classification of civil, dual-use, or military purpose; the size of satellites; rendezvous with one satellite or a constellation; specific danger situations: habitable modules, nuclear energy sources in close proximity, etc. (*the reality world in triadic concept*).

Since the problem that needs to be resolved in this game is an elaboration of space governance models for sustainable space activity (*the world of meaning in triadic concept*), the winner will be the player (in the case of competitive strategy) or group of players (in the case of cooperative strategy) minimizing the risks and achieving a responsible and economically reasonable strategy, that will be identified through debriefing.

A suggested PARDI mental map (Fig. 2.) has been developed for an open policy game wherein there is no predetermined correct solution to the initial problem, but optimal solutions can be discovered during the game by employing creative strategies. This paper puts forth a universal constructor, called mental "Lego", which allows interested stakeholders to construct a more tangible model of space governance based on the specific characteristics of a selected national legislations. While players may encounter challenges in navigating the dynamic nature of rule modifications resulting from rapid legislative amendments, this presents a unique opportunity for participants to actively engage in the development of regulations.

Within this broad framework, we can address more specific questions, such as the minimum safe distance between satellites. For example, in 2015 a Russian satellite Luch maneuvered between two Intelsat satellites, getting as close as 10 km. Later, in September 2018, France accused Russia of using Luch to spy on a military satellite jointly operated by France and Italy, and Pakistan's Paksat 1R and Russia's own Raduga 4 satellite 5 km and 10 km away respectively. Russian Academy of Sciences also noted that, several U.S.satellites—USA 253,254,270, and 271—have performed close approach maneuvers with non-cooperative satellites from Russia, China, Pakistan, and Nigeria at distances near 10 km [58]. The PARDI diagram, as a visual representation of satellite proximity scenarios, identifies predictive elements for detecting hostile behaviour, malfunctions, or other underlying causes. For example:

Problem: The lack of a common understanding of the minimum safe distance between satellites.

Actors: All satellite operators, national governing entities, and intergovernmental organizations such as the Inter-Agency Space Debris Coordination Committee (IADC) or the International Telecommunication Union (ITU).

Resources: Time, space surveillance systems (e.g., the public database of space objects called Space-Track), and other related assets.

Dynamics: Approaching or moving away, the goals of space objects,

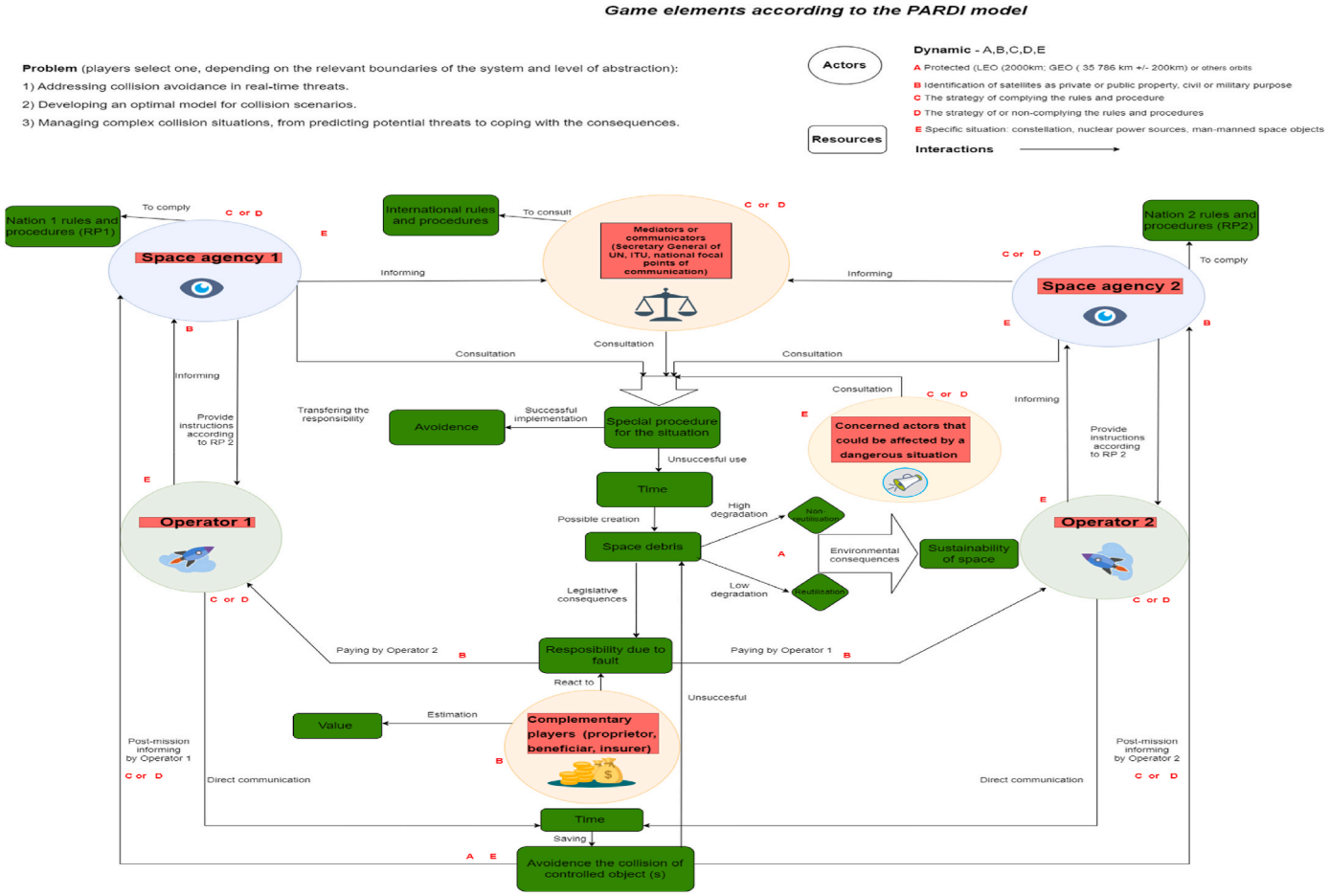

Fig. 2. PARDI model of the holistic serious game on space sustainability.

openly declared intentions, or hidden motives.

Interactions: Direct communication between operators, public discussions, exchanges of diplomatic notes, or even a lack of response.

This structured approach provides a clear framework for analyzing and addressing the challenges of satellite proximity and safe distances.

Using the example of determining the safe distance between satellites, we have identified a significant gap: the absence of a common understanding of this concept among spacefaring nations. For instance, various guidelines, such as the NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook [59], the ESA Space Debris Mitigation Requirements [60], and the IADC Space Debris Mitigation Guidelines [61], utilize differing thresholds to define close proximity (e.g., likelihood of collision greater than 1 in 10,000; 10^{-4}; 10^{-6}, etc.) and have inconsistent definitions. Moreover, the enforcement of space debris mitigation requirements often depends on the discretion of the approving authority, which may vary based on specific circumstances. In practice, states may fail to adhere to established safe distances, justifying their actions with differing measurement methodologies. In this context, the PARDI framework could serve as a valuable tool to facilitate coordination and reconciliation.

This approach fosters creative actions aimed at prevention, avoidance, transparency, and information sharing, tailored to the participants' strategies -whether lobbying for national interests (e.g., occupying orbital slots for espionage or potential attacks) or advancing common goals (e.g., preserving slots for future space activities). The strategies modeled in PARDI can be tested in various ways, considering the national laws, technical requirements, and interpretations of unsafe proximity. For instance, one actor might predict proximity based on their technical requirements and request an explanation from another actor. Depending on the latter's response, the first actor could adjust their assessment of the situation, determining whether the proximity is harmful or not. They might then develop a strategy for avoidance, either unilaterally or collaboratively, by notifying in advance or initiating maneuvers with or without prior notice. On this basis, participants of PARDI model (players) could propose algorithms to improve negotiation processes and recommend amendments to existing regulations.

6. Conclusion and future work

The gamification of complex issues enables a more effective means of communication compared to verbal/word explanations alone, as it allows individuals to directly experience and engage with the subject matter. Moreover, it facilitates the process of individuals with diverse backgrounds finding common ground and shared understanding through the creation of a collective experience. Our research demonstrates how core elements of gamification (abstraction, interiorization of simulation experience, non-linear form of reality reflection) and serious game construction (triadic concept and debriefing) can be a valuable tool in creating a holistic system-thinking concept (mental map) for sustainable space governance. Moreover, highlighting the shared characteristics between games and law has the potential to bridge the gap between these distinct areas of research. This approach avoids the perception that gamification is merely a tool for legal experiments used by gamers. Instead, it allows for the deconstruction of existing legal frameworks in space governance and the assessment of their validity. This can be achieved by either applying them based on the interests of the participants or challenging them to observe how interactions change in response to modifications. The proposed PARDI model serves as an invitation to all interested individuals to collaboratively construct a serious game that offers a fresh perspective on future space activities. This approach considers the current situation holistically, acknowledging the intersecting interests involved.

In conclusion, this research has the potential to further advance by transforming the developed mental map into a serious game that can be tested using various game mechanics. The authors believe that by collaborating with governmental and non-governmental stakeholders, this concept will yield fruitful results in gaining a deeper understanding of existing misconceptions within space activities (for instance, disposing of numerous satellites in the most crowded orbits, in spite of any warnings and rules). This work also has the potential to provide insights into crucial questions such as: How can we strike a balance between fostering the growing space economy and preserving the environment? How can satellites be protected in a cost-effective manner? How can we determine the jurisdiction and purpose of satellites, even if they are not registered with the UN, considering their constellation or dual-use nature? Lastly, how can we effectively clean up near-Earth space while grappling with uncertain communication protocols concerning property rights and jurisdictions? Exploring these questions through the proposed serious game holds significant promise for advancing our understanding of space governance and addressing its associated societal challenges. And thus, a more sustainable and responsible future in space governance will be paved, ensuring the long-term viability of human activities beyond Earth's boundaries.

CRediT authorship contribution statement

Anna Hurova: Writing – original draft, Resources, Investigation, Formal analysis, Data curation, Conceptualization. **Mélanie Becker:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Formal analysis, Conceptualization. **Nicolas Becu:** Methodology, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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