FROM DEBRIS TO DIPLOMACY: WHAT PLAYERS LEARN WHEN SPACE SUSTAINABILITY BECOMES A GAME

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Abstract

The Sustainable Space serious game is a dynamic and collaborative board game designed to address contemporary challenges in space governance, such as the fragmentation of regulatory frameworks, ambiguities in legal norms, and the absence of formal standards in emerging areas like in-orbit manufacturing. This paper presents a systematic qualitative analysis of multiple test sessions of the game, conducted between June 2025 and July 2026 across several international and institutional forums in Europe and Australia. The geographical and institutional diversity provides a robust empirical basis for assessing the game's pedagogical effectiveness and governance relevance. Participants spanned space engineers, scientists, legal and policy experts, and students from secondary to university levels. Feedback was collected through structured observation and verbatim comments, enabling cross comparison between expert- and novice-driven experiences. The analysis confirms that this serious game is consistently perceived as highly realistic, particularly in its representation of orbital congestion, space debris dynamics, satellite services, and systemic interdependencies between actors. Expert participants emphasized the game's capacity to make abstract governance problems tangible by forcing players to confront trade-offs between operational efficiency, legal constraints, and long-term sustainability. Negotiation phases were identified as a key strength, generating emergent behaviours such as coalition-building, informal norm-setting, shared risk management, and collective problem-solving. These dynamics illustrate the game's potential to function as a laboratory for experimenting with alternative modes of space governance beyond formal treaty-based frameworks. At the same time, the findings reveal structural limitations related to excessive rule complexity, insufficient onboarding, and strong dependence on facilitation. Notably, these tensions encouraged players to propose innovative governance mechanisms, such as cooperative debris-removal schemes, shared orbital responsibilities, adaptive regulatory arrangements, and incentive-based sustainability models. Overall, the results demonstrate that Sustainable Space game has strong potential not only as an educational tool, but also as a participatory instrument for exploring creative and practice oriented approaches to space governance.
Keywords: space governance, serious game, negotiation, sustainability.

I. Introduction

This article builds upon previous research that analysed the current governance of outer space and translated its key legal, economic, and political dimensions into the serious game "Sustainable Space", while incorporating feedback from aerospace engineers. The game models three interconnected dimensions of space activities, economics, law, and politics, and distinguishes between two complementary categories of space operations: Earth-oriented activities, such as remote sensing and telecommunications, and space oriented activities, including on-orbit servicing, close proximity operations, and orbital manoeuvring [2], [3]. The serious game addresses key issues related to sustainable space activities, including satellite

constellation management, collision risks, satellite services, international negotiations, and space law. Players operate across Low Earth Orbit (LEO) and Geostationary Earth Orbit (GEO), negotiate satellite services, and respond to realistic challenges such as space debris, orbital collisions, and natural and artificial incidents. The game mechanics are based on a modular system incorporating challenge cards, administrative cards, a token-based economy, negotiation mechanisms, and collective decision-making processes. The facilitation process plays a crucial role in shaping participants' understanding of the game, aimed for fostering trust among players, and ensuring an effective initiation of gameplay.

From this game, we aimed to deconstruct current models of space governance concerning sustainable space activity by implementing a participatory approach through development and organisation of simulation workshops. This process passed through two interconnected effects : on one hand, participants gain new knowledge about the system (pedagogical aims), and on the other, they engage in a reflexive process that lead them to reconsider how to address and overcome the current obstacles (mediation aims) [1]. These effects result from various mechanisms operating among participants during the workshops. Individually the participants learned about the constraints, objectives, and perspectives of other stakeholders, as well as gaining a better understanding of resource management and organizational processes. Collectively, the workshops revealed existing power dynamics and temporarily reconfiguration of the balance of power. not always correspond to the participants' professional backgrounds. In many sessions, roles were intentionally mixed to encourage participants to examine familiar issues from the perspective of other stakeholders, thereby fostering empathy, systems thinking, and a deeper understanding of the interactions between different actors. The objective of this article is to evaluate the results of a series of serious game workshops (play sessions/gameplay) using a simulation-based methodology and a defined set of evaluation artefacts. The following sections present the organisation of the workshops, the evaluation protocol, the evaluation results, and the main findings.

II. Material and methods

The serious game Sustainable Space was deployed in the framework of nine workshops from June 2025 to July 2026, each of which lasted at least three hours. (Table).

Date	**The name of workshop**	**The expertise of participants**	**Number of participants**
10.06.2025	International Workshop “Regulating Orbital Servicing: Liability, Oversight, and Space Sustainability” (UK)	Lawyers 60%, Engineers 40%	8
16.07.2025	International Simulation and Gaming Association conference (ISAGA)	Simulation and gaming	12
20.07.2025	French National Centre for Space Studies (CNES) (France)	Engineers	12
02.10.2025	International Astronautical Congress (IAC) (Australia)	Mixed (law, astrophysics, governance, simulation)	10
11.11.2025	Taras Shevchenko National University (Ukraine)	Students in geography	15

15.12.2026	Espace Mendes (France)	Secondary school pupils	5
21.01.2026	27th Course for Legal Advisors in the Armed Forces "Fundamentals of International, European and National Law Applied to Space Operations" (Italy)	Military 80%, lawyers 20%	60
06.03.2026	PSL Week (France)	Students in engineering	30
09.07.2026	The Space Executive School (France)	Mixed (law, anthropology, governance, simulation)	20
Total – 174			

The evaluation was based on direct observation during gameplay, followed by both oral and written debriefing sessions, guided by facilitator, the person is capable to create experience that goes beyond the game artefacts, and it assess patients' progress and performance. Following the oral debriefing session, structured around three guiding questions : "What aspects were successful?", "What aspects presented challenges?", and "What elements should be updated?" [4]. The participants were asked to complete a written debriefing questionnaire, established in accordance with the guidelines proposed by David Crookall [5]. The questionnaire gathered participants' backgrounds, assigned roles, and responses to 20 evaluation items: 1) What were your feelings/emotions during the role playing? 2) How did your emotions influence: 3) What happened? 4) How well do you feel your role and team succeeded in the negotiations? How well do you feel the others succeeded? Why? 5) How did your trust evolve during the exercise? What influenced the changes in trust? How did levels of trust influence decisions and interactions? 6) Did communication problems influence events? 7) How did negotiation styles influence outcomes? 8) What factors encouraged success? What factors made things difficult? 9) Which indicators influence the choice of one or the other (time, respect, certainty, etc.)? 10) What kinds of objectives did you have? How did they evolve? Did you attain your objectives? Why / why not? If you did not, who was responsible? 11) What differences and similarities did you see between the simulation and reality? 12) What elements in the simulation influenced your sense of confidence? Why and how did these elements influence your confidence? 13) What specific difficulties did you experience? 14) Which strategies do the players use for resolving the dilemma of personal and common interests within the space activity? 15) How does each factor relevant to these interests (financial, security, technological, cultural, legal) change the balance achieved by each strategy? 16) How would you change the simulation? 17) What thoughts or ideas have changed, or new ones been generated, as a result of participation? 18) What advice would you offer to the simulation designers and/or the facilitators? 19) What advice would you give for modification of space sustainability in the real life? 20) In what ways will this simulation experience influence your future outlook and your future career (if any)?

These questions are structured by three elements (play, meaning and reality) should to be reflected as a core of games with a purpose beyond entertainment (serious games) according to the triadic game design [6] or overlap between pedagogical theory, subject matter content, and game design [7]. Thus, this evaluation will be structured according to the blocks of game mechanics, meaning that was interiorised by respondents of debriefing by the passing through the game and recognising real-world elements of space activities,

which participants encounter in their professional or everyday lives, through game elements. These blocs help to understand better how the pedagogical aims were achieved. At the same time the mediation aim of participation approach to deconstruct space governance issue through space game playtest was analysed also through the block of evaluation of the facilitation style and their role in deconstruction, the problems faced according to some limitations. Special attention will be paid to the cohesion among key design elements and their alignment with the game's purpose, following the SGDA Framework proposed by Mitgutsch and Alvarado [8].

III.1 Game mechanics : General consideration

According to K. Mitgutsch and N. Alvarado, not only the players' mindset and the contextual framing of the play situation influence the impact of serious games, but also the way the games' purpose is channelled through their conceptual design. If the design of serious games is based on the specific explicit purpose to impact the players beyond the game itself, this intention has to be conceptually considered in every feature of the game during the design process [8]. From this perspective, the perception of design by players makes an important insight in evaluation of the game. The simulation highlights the complex interactions between technical, economic, political, and legal aspects of space governance. It confronts players with an ethical dilemma: maximizing individual team profit versus collaborating to maintain a sustainable, debris-free space environment. To bridge this gap, the game uses a "sustainability points" system. Since teams need at least one sustainability point to win, they are inherently incentivized to cooperate through shared services, confidence-building transparency, and debris mitigation.

The game based on the real harshnes of the space environment, but simplify the care about consequences to not overload the game mechanic and perception of players. Participants consistently recognised the game mechanics as one of the simulation's principal strengths. Their elements transformed abstract orbital concepts into concrete visual representations, making the simulation accessible even to participants with limited prior knowledge of orbital mechanics. Rather than addressing isolated technical problems, the game encouraged participants to consider interdependencies between satellites, orbital positions, service provision, legal obligations, economic constraints, and environmental risks. Many respondents reported that this holistic perspective enhanced their understanding of how technical, political, legal, and commercial decisions interact within contemporary space governance. Such systems thinking was considered one of the game's major educational contributions. various challenges, and ultimately demonstrated that both dimensions are contingent upon the applicable legal and regulatory framework. This mechanism was perceived differently by participants across the game sessions. For instance, one observer identified a deliberate strategy [8] of destabilising participants by altering the rules in order to challenge players' expectations and prompt them to critically reconsider their established modes of thinking: «The legal framework cards that come into play after the first round are interesting because they disrupt the participants' initial "classical" understanding of the game.»

While this design intended to reduce the initial cognitive burden, participants instead perceived it as fragmenting the learning process, forcing them to continuously revise their understanding of previously learned rules. Participants sometimes have problems with understanding of the satellite service provision, orbital rotations, differences between clockwise and counterclockwise movements, orbital revolution periods, and

especially the economic mechanisms governing revenues, payments, loans, and financial exchanges. These elements required considerable facilitator intervention before players felt confident making strategic decisions. Although participants understood individual missions, many remained uncertain about the ultimate purpose of the game, the criteria for success, and the relative importance of different strategic priorities. This ambiguity occasionally reduced participants' ability to formulate coherent long-term strategies. This raises questions about the game's pedagogical impact.

Despite positive evaluations, participants also identified several limitations affecting the game mechanics perception. One of the main challenges during the game design process was determining the appropriate level of abstraction. The objective was to achieve a sufficient degree of aggregation to represent the complexity of real-world space activities in a manner that remained credible to domain experts while preserving the game's playability and engagement.[3] The playtest showed that the most frequently reported issue concerned the overall complexity of the rules. Many respondents indicated that the game introduced new mechanisms progressively during gameplay rather than presenting the complete system at the beginning. The game dynamics were designed to progressively introduce participants to the broader context by gradually increasing the complexity of the challenges involved. The process initially focused on developing an understanding of the economic dimension, followed by the introduction of impact. According to Mitgutsch and Alvarado [8], assessing impact requires a clearly identified purpose that guides the entire game system. Unlike entertainment games, serious games are driven by an external purpose that shapes design coherence, though player interpretations may still diverge [28]. The game aimed to highlight the complexity of space governance through three dimensions: physical risks in a congested and contested environment, economic impacts of resolving harmful situations, and the legal influence on these dynamics. Player feedback revealed frustration but also confirmed the interconnections between these dimensions, an intended hidden aim of the design. These dimensions align with broader research goals: mitigating misunderstandings in uncertain communication, improving legal and policy framework comprehension, fostering mediation skills, addressing cognitive biases, and testing new best practices. Their success will be evaluated through the following analysis [2].

III.2 Game mechanics : Suggestions for modification of game mechanics

The most frequently mentioned area for improvement concerned the understanding and presentation of the rules. Participants repeatedly referred to the difficulty of understanding the game immediately, particularly the functioning of teams, orbits, satellites, negotiations, repairs, debris, and challenge cards. One participant explicitly suggested: "Explain the actions of the challenge cards", while another noted that "The rules were rather complex to understand immediately; perhaps this point could be improved." Similar concerns were expressed through proposals for "A video tutorial for introducing the game", a QR code with an explanatory video, a reference sheet for the cards, and a demonstration of one complete round during the introduction. This issue appears particularly important because it directly affected players' ability to participate in the game dynamics. The observation that "One participant who was not attentive during the explanation of the rules had not understood how the orbits worked, nor identified their satellite and the role it played" illustrates how an initial gap in understanding could prevent a player from fully entering the simulation. Another interesting misconception about the game mechanics and their exact representation of reality come from the commentaries of lawyers. One of them stated that "I didn't understand why there was a reason to pay other teams for going through space above their territory since that is not a principle that exists in the real world and contradicts

the principle of free exploration of use of space in the OST" However, this clearly refers to the provisions of Article 1(2) of Outer Space Treaty [9]. The game rules require Earth citizens to purchase space services from operators in orbit, ideally from the one above their territory or, if unavailable, from a nearby operator.

Two misconceptions arose: participants thought payment was for passing through space rather than for the service itself, and they assumed the passing team, not the region's inhabitants, was liable. Another lawyer in the same session shared this interpretation, suggesting broader issues: "Changes in teams (late arrivals/people leaving) and the fact that everyone was playing for the first time made things more difficult". It should also be noted that this misconception was not limited to this session and required additional time from facilitators for explanation and clarification. Therefore, moving beyond the individual circumstances of the participants and considering the issue from a meta perspective, it can be argued that the design of the game itself may contribute to this misunderstanding. The game board and satellite-based dynamics tend to keep players' attention focused on the outer-space dimension of the simulation. Although the game is intended to represent the provision of space services to users on Earth, the inhabitants of the Earth are not represented by distinct game artefacts; they appear primarily through the geographical division represented on the board. As a result, their interests can easily become secondary or disappear from the players' attention.

This effect may be further reinforced by the multifunctional role of the financier. The financier simultaneously addresses the financial needs of the operator, for example, the resources required to repair or restore the satellite, and the needs of the inhabitants of the state of registration by ensuring the provision of space services to them. In the players' perception, these distinct functions may therefore become conflated into a single financial objective. Since the operator is represented as a distinct actor within the game, while the inhabitants of Earth remain largely in the background as part of the game's contextual environment, the interests of the latter are less likely to be actively represented in decision making. From this perspective, improving the game could involve personalisation of the actors and interests represented within the game dynamics.

Making the interests of terrestrial users and other stakeholders more explicitly visible through dedicated game elements or decision-making mechanisms could help preserve the distinction between the different actors involved. At the same time the lack of understanding all elements of complexity leads to outline the most important and one of the participants said that complex game dynamic helped concentrated on the essential, i.e. space debris remediation : "I think we all were learning how things worked (in the game) as we went which made us less certain about what we were meant to do apart from avoid debris, and so maybe we were more cooperative compared to the real world (at least compared to companies in the real world, maybe countries and scientific organisations would be more cooperative)". There is a certain pattern in that some players ask for the rules to be simplified, whilst others ask for new elements to be added, such as specific states and their geopolitical interests, or positive cards to counterbalance the challenge cards. Several respondents proposed giving more time to become familiar with the rules, providing a memory aid, and including a simulation of one round. At the same time, some participants suggested the opposite direction: "Simplify the rules" and "Having fewer things happening at the same time, especially at the beginning, to better understand the game." This apparent contradiction is analytically significant. The game was designed precisely with the intention of placing players in a state of uncertainty, mirroring the real situation in space; therefore, the playful aspect of the design competes

with the need to convey the actual state of affairs, including the psycho-emotional context of real space actors when operating in a situation of uncertainty. This indicates a tension between the intended use of time within the game and its actual use by participants.

Time that was intended to allow players to understand the rules, assume their roles and progressively enter the simulation could instead be consumed by prolonged negotiationsThus, game pacing emerges as an important design variable, and facilitation becomes necessary to maintain the intended progression between learning, interaction, negotiation and decision-making. An important finding emerges from the contrasting requests made by participants. Some respondents asked for additional layers of realism, including geopolitical issues, human spaceflight, military and scientific drones, cultural interests, and more detailed orbital dynamics. For example, participants suggested: “Take human spaceflight and human-related issues into account”, “I would change the rules so that they include geopolitical issues”, and “Perhaps add more space-related elements”. This divergence reveals a classical design tension between abstraction and aggregation. Some participants experienced the abstraction as excessive and sought additional contextual elements to make the simulation more recognisable as a representation of the real space sector. Others experienced the same game as already sufficiently complex and requested simplification. It could indicate that participants evaluate the game according to different expectations regarding what a serious game should reproduce.

For example : “It felt less realistic because we were all joking and not taking it too seriously, but I preferred it that way because I wanted to have fun with it more than have it be perfectly realistic”. The requests to make the game simpler also need to be interpreted in relation to the role of uncertainty in the game design. Participants frequently expressed difficulties with unclear situations, complex negotiations and unexpected consequences. However, reducing uncertainty would potentially weaken one of the central idea of the game. It was designed to place participants in situations where they cannot fully predict the consequences of their decisions. This corresponds to the actual conditions of space activities, where actors must make decisions despite incomplete information, technological uncertainty, regulatory fragmentation and the actions of other stakeholders. between the operator and financier roles” and suggested: “Remove the two different roles (operator-financier) and simply allow players to choose their roles.” However, it is necessary to take into account that, according to the game designer’s conception, the two roles serve at least two purposes: 1) to reflect a real-world situation in which a significant number of interests can influence a single decision, making unilateral decision making impossible at times and therefore requiring negotiation; and 2) given the large number of elements that players need to keep in mind within the game mechanics, the distribution of roles allows each team member to focus on their respective area of responsibility. This is intended to help players keep track of the different elements of the game and avoid reacting automatically, instead enabling them to engage with the game dynamics in a more gradual and conscious manner, taking different factors into account and weighing them when making decisions.

Another group of recommendations concerned the balance of challenges and rewards. Participants noted that there were “Too many situations where satellites become immobilized” and that “too many negative event cards reduce the importance of operational/exploitation negotiations.” Others proposed adding “‘gain’ cards”, refining the rules and varying the consequences of challenges. Similarly, one participant suggested adding a debris card from the very first turn, while another proposed toning down certain “collision” cards that “throw the balance of power completely out of kilter.” These observations indicate that the distribution and intensity of random events influence not only individual player experience but also the strategic balance of the simulation. If negative events dominate too strongly, players may become primarily reactive rather than strategic.

Conversely, introducing positive or compensatory mechanisms could allow participants to recover from adverse events and maintain meaningful strategic agency.

Consequently, the participants' demand for greater clarity exposes an important design dilemma: the uncertainty that makes the simulation realistic may simultaneously make it difficult to play. The objective should therefore not necessarily be to eliminate uncertainty, but to distinguish between meaningful uncertainty, which forms part of the learning objective, and uncertainty about game mechanic, which results simply from players not understanding what they are allowed or expected to do. The division between the operator and financier roles generated particularly interesting feedback. Participants reported that "It was difficult to distinguish between the operator and financier roles" and suggested: "Remove the two different roles (operator-financier) and simply allow players to choose their roles."

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The issue is therefore not simply whether challenge cards should be added or removed, but whether the distribution of risks and opportunities allows players to perceive a meaningful relationship between their decisions and their outcomes. At the same time, it is worth noting that, as with the element of uncertainty, the game designer's main intention was precisely to highlight the dangers of unsustainable space activity consequences, perhaps even in a manner slightly exaggerated compared to reality, in order to draw attention to this issue and encourage players to reflect on it; that it seems to be achieved. Since the aesthetics/graphics present the game to the player from the first image on, it plays a fundamental role in the introduction of the game's purpose and its impact on the player.[8] The visual aspects of the game were generally assessed positively. Participants described the board design as "excellent" and the cards as "very beautiful", while recognising "a lot of potential". At the same time, suggestions were made to make the map larger, include an example of how a game unfolds, and distribute the cards more equitably according to their respective specialisations.

Others noticed the visual complexity of several cards reduced usability. Participants frequently reported that dense textual information and inconsistent iconography slowed

decision-making, particularly during negotiations conducted under time constraints. These recommendations suggest that visual design is not merely an aesthetic component. In a complex simulation, the board, cards and other visual elements function as cognitive interfaces through which participants understand the state of the game. Improving their organisation and visual hierarchy could therefore contribute directly to reducing cognitive overload.

III.3 Game mechanics : Strategies of Interaction Between Players

Communication is central to the game's mechanics and warrants detailed analysis. Players identified success factors such as exchange, collaboration, luck, cards, economic and material attractiveness, trust in forecasts, strategic thinking, speech formulation, and time pressure. For many, financial success was key; for others, sustainability points mattered most. A lot of observers pointed out that the logic of negotiations was similar regardless of the subject and the teams. At the same time, the teams adopted different strategies that seemed to be indirectly related to their understanding of the game rules, and therefore to their confidence in their own situation and decisions throughout the game. Some participants felt frustration and asked to « add a little more contextual information about the possible strategies ». Communication was difficult within some teams, with different understandings and visions of the objectives required to win the game. In one team, one of its members conducted most of the negotiations alone without consulting their teammate. This same team had a limited understanding of the different game mechanics. Between teams, communication also appeared to affect strategic positioning and the choices that were made. One team, for example, seemed to have a principled opposition to every proposal made by the opposing team, even when the proposal was beneficial to both parties. The observer from the Space Executive School session outlined some styles of interaction: overall cooperation, a "wait-and-see" strategy adapting to the different teams, and an individual strategy. "Wait-and-see" strategy: limiting themselves to the game rules (minimum payment of 1 astrocoins (money in the game), etc.), without attempting to establish coordination, and waiting for proposals.

Personal interest only: this led to a sunk cost fallacy because the team in question encountered several restrictive cards and, following a misinterpretation, considered one of the other teams to be acting against them, including when cooperation around their common interests was proposed.

Systematic cooperation proposals: the team attempted to gather the maximum amount of assets required to win the game (astrocoins and sustainability points), while taking short-term risks (proposing to pay for the purchase of a new satellite, proposing to form a single unified team with decisions about actions being taken in turns, etc.). Another interesting observation was made during the play session at The Space Executive School. The observer stated that some cooperation proposals that appeared to benefit the party in difficulty turned out to be driven by longer-term interests that contributed to winning the game, for example: a) proposing to form a single team in order to collect astrocoins more easily ; b) proposing not to charge for a service/repair following damage, with the cost being paid in sustainability points rather than astrocoins ; c) roposing a service contract that would remain the same each time the zone was overflown, thereby ensuring a minimum income higher than that imposed by the game rules.

Thus, a good understanding of the rules, having already played the game, and the willingness to keep making proposals even after receiving only refusals were factors that contributed to success, or at least did not reduce its likelihood. Poor communication within the same team, combined with a complete misunderstanding of the initial rules, complicated the negotiation phases.

III.4 Game mechanics : Negotiations and Factors Influencing Them

Despite that negotiation, as a core part of the game dynamic, was recognised by some players as a factor that did not guarantee winning the game: “The group that negotiated best did not ultimately win”, it needs a special attention as a key factor of game dynamic. The important role was placed to emotional background of negotiations in the creation and analysis of the game dynamic. The players noticed that the most successful negotiations are those benefiting both sides, preserving good relation, fast, good-humoured, honest and least manipulative. But on the way of this standard, the players struggled a lot of real obstacles, for example one of the players remarked the lack of compromise because others did not communicate calmly. Some players recognised that « the discussion is based more on emotional arguments than on facts », but still others said that « aggressive negotiation did not work; it was necessary to present concrete arguments ». A lot of attention was given to such feelings as trust, certainty and aggression: « loss of trust toward the yellow team because of their greed, and toward the orange team because of debris without accountability or respect for the parties involved, as well as certainty that the service provided was the appropriate one ».

The most players highlighted the role of aggression that “creates camps, very greenwashing-style negotiations, many attacks and counterattacks, decrease the trust and damage relations”. Some players held the view that «aggressive negotiations generated more money», others had the opposite view « aggressiveness in negotiations had a negative influence » and the third group tried to find a compromise « aggressive strategy is advantageous as well as very soft, but neither one nor the other is not good ». Interestingly, the observers, as persons behind the game dynamics and therefore less involved, used another word than “aggression”, namely they called the negotiations “tenacious” or even “adventurous” and remarked on the dependence between the negotiation strategy and the tasks that players had to complete during the game: “at first, negotiations were simply about money; once the challenge cards appeared, negotiations involved less money and more partnerships to deal with the subsequent cards.” The facilitator noticed that the key question behind all negotiation was: “what do I gain from this?” This shows the key pattern that players followed when solving problems: competition based on the prevalence of their personal interests. The player says that there was a reason for that “breakdowns in agreements were encouraging people to be more self-centred”. At the same time alliances contributed to success: «towards the end, the allied teams used up the time and eventually imposed their choice on us without our agreements ». But only long-term alliances favoured success that need also trust and confidence. The worst situation was where « operator and the finance specialist disagreed ».

There is also a tendency to oppose players with more resources: « Everyone tried to be fair, therefore disadvantaging the richer players; When one team monopolizes the resources of all the parties, it is very difficult to negotiate with them». Negotiations reflected the perception that states tend to cooperate selectively, particularly with actors perceived as sympathetic, powerful, or strategically relevant. One of the strongest observations was how naturally players’ strategies reflected their personalities and communication styles. Participants tended to identify themselves with major space powers, reflecting a psychological tendency to align with authority and dominant actors. It was noticeable that very proactive behaviour can sometimes hinder cooperation by creating emotional barriers within a team: «It was difficult to assert oneself when faced with strong personalities ».

The game engaged peoples from different professional background, but they experience as a gamer as their additional profession or as amatory changed the game perception, strategies an interaction with other players. For example, one of the observers noticed that

one participant mentioned at the end that she had already had the opportunity to play the serious games, which, in hindsight, is reflected in the strategic approach she adopted: overall cooperation, frequent proposals for agreements with the other teams, and the use of language designed to demonstrate their 'goodwill', etc. Some players noticed that "basic negotiation strategies not linked to the international law applicable for space". Criticism of the freedom and creativity in the game mechanics afforded to participants. Interestingly, there is no criticism regarding non-compliance with international law, as the rulebook contained extracts from international instruments to be applied during the game; the participant points out that failure to comply with them was not due to international law, but rather to shortcomings in the game mechanics. Thus, negotiations as an important part of game dynamic shows importance of emotions, like trust and aggression and creation of alliances that could be on the emotional or reasonable background.

IV.1 Interiorised meaning : General considerations

The key narratives, transmitted by the game, received highly positive evaluations across all participant groups. Both experienced professionals and participants without previous expertise reported finding the scenarios engaging and intellectually stimulating. Experts appreciated the realism and policy relevance, while novices considered the simulation an accessible introduction to complex space governance issues. The integration of international space law was viewed as particularly valuable. Rather than presenting legal concepts through conventional lectures, the simulation embedded legal questions within operational decision-making, encouraging participants to explore issues such as liability, sustainability, satellite operations, and environmental protection through practical negotiation exercises. This experiential approach was perceived as enhancing both understanding and retention of complex legal concepts.

IV.2 Interiorised meaning : Immersion

The game might not offer a linear story, or simulate or represent a specific issue, but provide a mechanic based space that enables players to create their own stories.[8] The game sparked interest from the beginning, creating a good entry point for immersion and learning: "I was quite intrigued by the game; it was a pleasure to learn more about space". The design aimed to reflect the complexity of managing space-related issues, including at the emotional level, which was perceived by the players: «The event cards, because of their surprise effect and possible consequences, created stress »; "I think the game reflects reality quite well. Seeing the cases explained during the week (the author means The Space Executive School) makes them much more concrete and real"; "The contextualization was good and made the whole experience quite realistic". Both the game dynamics and group interactions influenced the level of immersion: « earning money makes teams more confident and encourages them to participate »; « a cheerful atmosphere also helped to relax». There was a lot of frustration related to certain game elements, particularly the rules, but some players highlighted that: "repeated explanations of the rules, such as the two instructions per round, allowed for greater immersion in the game." Some players perceived the playful context as preferable, as it facilitated the learning process and strengthened the connection with reality.

This may also be related to the quality of facilitation, which will be analysed below: «The enjoyment of the game motivated me a lot; It was difficult to get into the role and therefore to take the others seriously". The characteristic that negatively affected immersion was that the rules were not provided in the players' mother tongue. For the Italian experts, Ukrainian

students and the international French students, the game was conducted in English that criticized in debriefing.

IV.3 Interiorised meaning : Learning results

The participants responded to questions about the thoughts and ideas that changed or emerged as a result of their participation in the game, providing insights into how they perceived and assimilated the sense of problem issue through their game experience. For some respondents, participation broadened their understanding of space activities and enriched their general knowledge of the issues surrounding space exploration, while also contributing to a better understanding of international tensions and the importance of taking responsibility for satellites. For others, by contrast, the game brought them into contact with concrete dilemmas that challenged their general assumptions. It helped them better understand the complexity of space activities, made the issues of cooperation and competition more tangible, and encouraged a more critical view of commercial narratives in this context, for example: « space is not actually that large, especially around Earth»; «exploitation of space resources»; « distinguish between projects motivated by scientific objectives and those motivated by economic gains ».

In both cases, the responses showed that the game designer's aim of encouraging participants to perceive the need to strike a balance between different interests was realised: "My objective was to maintain a balance between money and reputation, but because of excessive diplomacy, we didn't end up with much money. This was probably partly stimulating, but on the other hand, a bit frustrating." The participants also identified several personal insights that were indirectly related to the game and its subject: "The serious game seems very promising for raising awareness about different aspects of space, and I personally enjoyed and learned a lot from it"; "The game is a playful way to understand better complexity"; "Awareness about sustainable themes; importance of choosing alliances"; "I should reflecting on the stakes and everyone's positioning before speaking» ; « I realized how difficult negotiation is and how important the element of chance can be» ; «This experience taught me a lot and increased my interest in the field » ; "I get that isn't easy to reach goal with balance". The game experience also motivated them to learn more in the future: "I intend to follow developments in the space sector and explore it further"; "I want to learn more about geopolitics in space". Even though the players did not have a direct impact on this sphere, the game experience increased their awareness of the issues involved: « I am more aware of the interests of large companies that invest in the services we use every day».

Different levels of learning effects can be identified through the lens of Argyris and Schön's theory of single- and double-loop learning that correspond pedagogical, and mediation aims that are analysing in this article. Single-loop learning involves acquiring new information and recognising elements of a systemic issue, whereas double-loop learning involves questioning the underlying governing variables themselves and subjecting them to critical scrutiny [10]. Some respondents reported discovering new information that they had not encountered before: « I am not sure I will pursue a career in the space sector, but sustainability issues are now firmly in my mind»; « The idea of satellite repair emerged for me». Others highlighted that they deepened their existing knowledge or even formulated perspectives on approaches to managing the problem of space sustainability: «I better understood the importance of sharing equitably and that space should belong to no one» ; «Without common rules, there is only chaos»; «Individualism should be avoided and long-term thinking should be encouraged » ; «Power/strength should not be allowed to interfere

in negotiations; actors should act in the collective interest» ; «The general interest must also be considered, and dialogue is necessary without simply allowing everything».

Another aspect of the analysis concerns the narratives that players assimilated through the game and suggests as a solution for the real life, as reflected in their responses to the question «What advice would they give for modification of space sustainability in the real life? ». This demonstrates their role not only as passive recipients of information, but also as active participants in reflecting on real-life issues. Regardless of whether they were students or aerospace engineers, participants contributed according to their knowledge and capacities.

Based on the analysis of the responses, the suggestions can be structured into the following categories: a) rules: «Regulation of what is allowed or not allowed. Introduce stricter regulations to prevent abuses Unsustainable space pollution should be sanctioned at the source. Stricter laws regarding what is sent/launched into space. We should create a legal entity that would genuinely punish violations in space » ; b) transparency and cooperation: « Cooperate even more in order to achieve common goals. More extensive discussion among the different actors to limit the impact of personal interests, which are often not sustainable: international collaboration. Necessity of collaboration while keeping one's own interests in mind. An understanding of the issues and ways of thinking of the various stakeholders. Greater transparency regarding satellite objectives. One must be able to negotiate and listen in order to find compromises that work for everyone. In that case, I think it is important to conduct international programs so as not to be "abandoned" in the event of a technical problem. The establishment of cooperation frameworks, particularly where sovereignty issues are involved, and especially frameworks that are more stringent when such stakes are present » ; c) environmental issues: "Talk a bit more about environmental notions. Better maintenance of satellites, recovery system. The importance of avoiding collisions! Organize independent repair centres » ; d) common interest and individual responsibility: «To make it clear to countries that space is a shared resource. Pool satellite data among nations and reduce privatization. Focus on missions that have meaning for humanity. Actors need to take more responsibility for the debris they produce and send into space. Greater individual responsibility regarding debris ».

V. Transition of reality

The realism of the simulation emerged as the most frequently cited positive aspect, particularly regarding the representation of operational constraints faced by space actors. For example, the space engineers from the playtest in French National Centre for Space Studies (CNES) noticed that game: "helps players understand the practical challenges of sustainable space"; "offers a wealth of insights into the satellite system: the complexity of situations and services in orbit, the difficult situations encountered, conflicts, and instances of negotiation or compromise". The space lawyer from the game workshop during International Astronautical Congress (IAC) also positively marked representation in the game: the technical standards and harmonised compliance mechanisms, but utopian: sanctions for debris and limits for constellations. The negotiation format promoted interdisciplinary dialogue. Participants from different professional backgrounds were encouraged to explain their perspectives, negotiate compromises, and collectively address complex governance challenges. Such interactions reflected many characteristics of real international space negotiations, where technical, political, legal, and economic interests must be reconciled. The participants noticed that simulation was easy because you can do mistakes, but in the reality the diplomacy has a bigger in weight and impact.

Respondents particularly appreciated the richness of the documentation supporting the simulation and considered the scenarios sufficiently realistic to illustrate current challenges in space governance. One of the participants noted that a lack of knowledge of the rules meant

that everyone had their own interpretation, and that this is a reflection of the reality of space governance, where general rules lead to the same effect, so it can be noted that this circumstance led participants to a deeper understanding of the complexities that exist in the real world through the game, which was reflected in the relevant comments by some participants on the importance of clear norms of space law. This is, in fact, not only the pedagogical but also the mediation role of the game: a deeper awareness of the situation, not only through understanding how it works, but also through understanding how those who face the same issues as the players in real life feel. This highlighted the connection with reality: when the rules are unclear, it leads to multiple interpretations. Rather than reproducing reality in a fully detailed or literal manner, the simulation adopted a deliberately simplified and fluid structure. As one participant observed, it was "a playful approach, therefore less structured and more fluid than reality." This simplification nevertheless allowed participants to reproduce several patterns of behaviour characteristic of contemporary space governance.

Although the game explains complex governance objectives, players almost always focused on tangible goals such as increasing their budget, while often overlooking a key rule, not leaving any region of the Earth without essential space services. It mirrors reality, where measurable objectives frequently take priority over broader challenges such as space sustainability, societal well-being, or climate change.

A particularly significant aspect was the emergence of «actor strategies resembling those observed in international relations». Participants frequently reintroduced the current geopolitical context into their negotiations, despite the game not explicitly assigning them to particular states. One observer noted that «we clearly observed actor strategies similar to those found in today's world », identifying a tension between coalition-building and individualism: «Russia and China were perceived as more individualistic, whereas other actors tended to collaborate». This observation is particularly relevant because the game design intentionally avoided assigning participants specific countries, instead representing broader geographical regions. The persistence of country-based interpretations may therefore be understood as a strategy for reducing uncertainty.

This tendency also demonstrates participants actively reconstructed reality within the simulation. They selected existing countries as reference points, interpreted regional actors through their knowledge of international politics, and reproduced assumptions about national interests. As one participant stated, "I think that both in reality and in simulations, states prioritize their personal and national interests." Interesting point is identification of individualistic approach for making decisions according to space debris proliferation: "They did not want debris in their own areas, even though they share the same space". The game did not need to reproduce actual diplomatic procedures in their entirety to generate this dynamic. By creating interdependent actors with partially divergent objectives, it produced situations in which participants had to negotiate between collective benefits and individual gains. The complexity of these interactions was explicitly perceived as contributing to realism: participants referred to "the complexity of negotiations and the defined zones" as similarities with reality, while others highlighted bargaining over services and partnerships.

At the same time, the degree of perceived realism varied considerably among participants. This variation appears to have depended not only on the participants' level of expertise but also on what they expected the simulation to represent. Some participants considered the simulation "very realistic thanks to the negotiation aspects, debris, unexpected events," whereas others regarded the scenarios themselves as implausible while considering the negotiations realistic. For example, space engineer noticed: "I come from space operations, and I don't think the game is representative of real space situation, and it is necessary more technical people to contribute, but simplifications may be needed for the

game". One explanation is that experts tend to evaluate realism against the detailed institutional, technical, or political characteristics of actual space activities and therefore identify omissions more readily. For example, the space lawyer that have a significant background of practical work in this sphere righty pointed out that the game mechanic is not represent the real mechanics of turning of satellites in geostationary orbit, because they should stuck on the same position concerning the Earth, instead the Earth should move. That is the example where representation of reality was sacrificed in favour of simpler and more convenient game design and mechanics standardized across both orbits.

By contrast, for participants without extensive exposure to the space sector, the same level of abstraction may be sufficient to produce a strong sense of realism. Consequently, perceived realism could be understood not as an objective property of the simulation alone, but as a relational construct emerging from the interaction between game design and the player's prior knowledge and expectations. The same phenomenon can be observed in relation to the roles assigned to players. Some participants considered the simulation insufficiently realistic because the actors associated with geographical zones did not necessarily have the same interests as corresponding real world actors. Others suggested that the roles of the satellites should have been more clearly defined. This indicates that abstraction, while useful for avoiding overly deterministic representations of real-world actors, may simultaneously increase uncertainty to a point where participants struggle to identify the perspective from which they are expected to negotiate. The comments therefore suggest a design trade-off: the less explicitly a role is defined, the greater the freedom for participants to construct their own strategies, but also the greater the risk of weakening the connection with the real-world context and a lot of frustrations for the players that have not the space background.

Another important mechanism connecting the game to reality was uncertainty and chance. Participants repeatedly referred to event cards, dice, accidents, and unexpected events as elements that made the simulation realistic. One participant argued that "there is an element of chance to manage through the cards and dice, which should be retained because it represents reality," while another considered chance to be "at the heart of the game." These observations suggest that unpredictability functioned as a proxy for the uncertainty inherent in space activities. However, the same mechanism could also undermine perceived realism: some participants interpreted the prominence of chance as evidence that the simulation was less representative of actual decision making. Thus, chance operated ambivalently as a mechanism for reproducing uncertainty, but also as a potential source of perceived artificiality.

The relationship between game simplification and realism was similarly ambivalent. Participants identified differences from reality in the distribution of debris, the simplicity of events, the limited number of possible negotiations, and the management of money. The last one was described as "the least realistic aspect," while another participant noted that the game was more limited than reality because "the rules are not enough" to encompass the full range of possible negotiations. These observations indicate that simplification facilitated playability but inevitably altered the incentive structure of actual space activities. This was explicitly identified by participants who noted that negotiations were sometimes conducted "purely from a game perspective (astrocoins), rather than from a real-world perspective." Another participant similarly argued that a lack of realism resulted from the insufficient representation of political interests beyond financial interests, despite the relevance of military, scientific, and other strategic considerations.

Finally, the simulation's connection with reality was strengthened by the introduction of different legal regimes and regulatory constraints. Participants considered it realistic that different areas were subject to different legislation and reported that this made the distinctions between legal regimes difficult to understand. This difficulty is particularly valuable from a pedagogical perspective: rather than presenting law as a static background condition, the

simulation made regulatory differences operationally relevant to players' decisions. The game therefore transformed legal diversity into an experiential problem of coordination and negotiation. Overall, the observer indicate that the game's realism emerged less from its literal reproduction of the space sector than from its capacity to generate recognisable decision-making dynamics.

Negotiation, competing interests, coalition-building, uncertainty, strategic behaviour, regulatory fragmentation, and the tension between individual and collective interests were repeatedly identified as realistic elements. At the same time, simplification, the dominance of monetary incentives, insufficiently defined roles, and the prominence of chance sometimes weakened this connection. The game appears particularly effective when realism is understood as behavioural and relational realism, rather than as a reproduction of existing space governance structures.

VI. Role of facilitator and observer

The facilitator emerged as a central component of the learning experience. Across all sessions, participants consistently reported that effective facilitation substantially improved their understanding of the rules, reduced uncertainty, and maintained the pace of negotiations. Rather than simply explaining mechanics, the facilitator acted as a mediator who supported discussion, encouraged participation, and helped participants connect gameplay with broader legal and operational concepts. The motivation to be the facilitator explained by participants as “Managing to truly guide the players, be useful to them, and to undersatand why they wanted to negotiate certain choices and actions”. At the same time, they struggle with difficulties “to facilitate without having understood everything that was complicated within a rather short time frame”. The responses also demonstrate that the effectiveness of the rules cannot be considered independently from facilitation.

Several participants called for “A larger role given to the game master/facilitator” and suggested that the progression of each round should be explained more clearly. This is particularly relevant because the game was designed to require players to navigate a relatively complex environment with the help of facilitator rather than simply follow a predetermined sequence of actions. The feedback indicates that some difficulties attributed to the rules may, in fact, emerge from the interaction between game design and facilitation. This is especially visible in the observation concerning the duration of negotiations. Participants stated that “The waiting time between rounds is too long” and that there was “Limited participation in important negotiations; we did poorly in the negotiations because the game had not progressed far enough in time.” Another participant similarly suggested that “it was good, but less time should be allocated to negotiations because they take too long.”

Lack of understanding rules influenced the confidence and immersion of the players into game dynamic. The remarcable was game test during 27th Course for Legal Advisors in the Armed Forces "Fundamentals of International, European and National Law Applied to Space Operations" (Italy). Facilitators were not familiar with the game more than to read of the game handbook and without making previous playtest. Furthermore, according to the large amount of interested to play the game and only 3 game kits available, they were obliged to facilitate the game with the amount of player that are larger than it was prescribed as recommended. To resolve the gap in understanding complexity of game mechanic, they often asked for explenation the game designer during the game to seek clarification on the rules; consequently, the facilitators’ lack of adequate training in fully understanding the rules had a significant impact on the participants’ understanding of them. As a result, a lot of players had a lot of confusion on the rules of the game, some even responded on the

question “What specific difficulties did you experience?” responded “participants’ chaos”. But not all see the reason only in the facilitator style or lack of knowledge or experience, some noticed that the factor of lack of time to understand rules.

The participants notice disadvantages of different styles of facilitation in the phase of briefing. From the one side they said that needed more time to understanding the rules and more explanations, and for another side, where it was done, they had the problems with disequilibrated time set, where long briefing leads to resalts where “the game was interrupted at the second turn, it is difficult to notice evolution”. The introductory phase was frequently considered too long and insufficiently structured. Participants indicated that a clearer onboarding process would have accelerated familiarisation with the rules and reduced initial uncertainty. Another challenge concerned the high dependence on facilitator support. Many respondents acknowledged that they would have struggled to understand the game mechanics without continuous explanations.

This reliance suggests that the current version of the simulation should be significantly reconsidered to implement autonomously in educational settings lacking experienced facilitators. The game is a communicative polylogue [11], especially in the such type of the games, where negotiations play a significant role. Even greater responsibility for deconstructing the game’s rules lies with the facilitator, who should convey not only the rules of the game itself but also the underlying meaning that the game seeks to communicate through its playful format. From this perspective, the facilitators’ communication skills can significantly affect the effectiveness of this process. During the playtests, participants perceived the facilitators as active and motivated and provided other positive feedback. At the same time, one participant’s comment was particularly noteworthy: she expressed surprise at some of the linguistic constructions used by the facilitator and noted that she needed more time than usual to understand the meaning of the explanations.

Further discussion of the reasons for this reaction revealed that the facilitator, originally Ukrainian, occasionally transferred certain communication patterns from her native language when formulating explanations in French, particularly the frequent use of double negatives, which can unintentionally create ambiguity or misunderstanding in French. This recommendation is relevant not only to observation but also to the research potential of the simulation. Since the game is intended to generate behavioural and negotiation dynamics, systematic observation could provide additional data on how strategies emerge, how relationships develop, and how conflicts and alliances influence decision-making. Such a modification could therefore strengthen the game not only as a pedagogical tool but also as a research instrument for studying negotiation and decision making in space governance.

VII. Conclusions

The analysis of the serious game’ Sustainable Space workshops results through the lens of the identifies three dimensions: game mechanics, the transmission of meaning and connection with reality, and the cohesiveness between these dimensions, lead to the following findings. The main idea was to demonstrate the complexity of space governance, reproduced through three dimensions: the physical risks of a congested and contested space environment; the economic impact of resolving situations arising from a harmful space environment; and the legal impact on the dynamics of the two previous dimensions. The players’ feedback provides evidence of same this complexity and of the frustration generated by it. At the time, participants also expressed complementary insights into the interconnection between these dimensions, which was one of the underlying aims of the game design.

The holistic perspective enhanced their understanding of how technical, political, legal, and commercial decisions interact within contemporary space governance. Such systems thinking

can therefore be considered one of the game's major educational contributions. Another important participant of the game workshops was observer, which provides valuable information beyond the context to be engaged in game dynamic. One participant proposed particularly valuable suggestion concerned the use of dedicated observers: "I would assign a specific observer to each team in order to really highlight the relationships, affinities, and conflicts. The observer should remain with one team in order to properly capture the dynamics and interests of that team."

The approach of introducing new mechanics progressively during gameplay, rather than presenting the complete system at the beginning, was perceived by some participants as fragmenting the learning process, as they had to continuously revise their understanding of previously introduced rules. This created frustration because of a mismatch between their expectations of a playful game and the complexity of the simulation. At the same time, however, it produced the intended effect of gradually recognising the relationships between the different game elements and their real-world counterparts and consequently supported their holistic understanding of the issues represented by the game.

Another aspect of the analysis concerns the mediation of meaning through the workshops and the narratives that players assimilated through the game, as well as the solutions they suggested for real-life space sustainability challenges. These included the understanding that unclear rules can lead to multiple interpretations; the importance of negotiation while taking into account the interests of all participants; the recognition that aggression is not a guarantee of success; the need to take care of satellites during and after their operation; and the importance of greater individual responsibility. These ideas are already widely recognised and are not necessarily novel in themselves, but their value, however, lies in internalisation by participants as convictions, because they experienced these principles through the game not only cognitively but also emotionally.

The analysis also provides evidence of the cohesiveness between the three dimensions of the game. During the analysis of different parts of the debriefing questionnaire, it became apparent that criticism or positive feedback concerning one dimension was often interconnected with another. For example, the playful effect created by the game's strong aesthetic representation influenced participants' motivation to discover the game mechanics and the meaning underlying the game. Similarly, difficulties related to the mechanics influenced participants' perception of the realism and meaning of the simulation. The participants' recommendations concerning the modification of the game can be grouped into several interconnected dimensions: clarity and accessibility of the rules, facilitation and game pacing, the balance between abstraction and contextualisation, the distribution of roles and responsibilities, the management of uncertainty, and the visual and material design of the simulation. Taken together, the responses indicate that the main challenge is to maintain a balance between the cognitive complexity required to reproduce the dynamics of real-world space activities and the accessibility necessary for players to engage effectively with the simulation.

The game was designed to place participants in situations where they cannot fully predict the consequences of their decisions. Consequently, the participants' demand for greater clarity exposes an important design dilemma: the uncertainty that makes the simulation realistic may simultaneously make it difficult to play. The objective should therefore not necessarily be to eliminate uncertainty, but to distinguish between meaningful uncertainty, which forms part of the learning objective, and uncertainty about the game mechanics, which results simply from players not understanding what they are allowed or expected to do. Abstraction, while useful for avoiding overly deterministic representations of real-world actors, may simultaneously increase uncertainty to a point where participants struggle to identify the perspective from which they are expected to negotiate. By creating

interdependent actor actions with partially divergent objectives, the game produced situations in which participants had to negotiate between collective benefits and individual gains. It should be noted that the assessment of the mediation objective is subject to certain limitations. Some workshops were relatively homogeneous in terms of participants' professional backgrounds and stakeholder representation, thereby limiting the diversity of interactions that typically characterise real-world multi stakeholder negotiations.

Further research will focus on reconsidering the game in light of the findings obtained through the workshops and expanding it to other space sustainability issues, for example, the use of space services for climate change management, the contribution of space activities to achieving the Sustainable Development Goals, or space resource management. Furthermore, it would be interesting to reconsider the concept of the game according to idea of considering seven generations before and seven generations after current space activities as a sustainability philosophy associated with Indigenous peoples that was suggested by one participant during playtests. This perspective could introduce a longer-term dimension into the game and encourage participants to consider the consequences of contemporary space activities not only for current actors but also for future generations.

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