EARTH UNDER SIEGE: THE GAME OF SUSTAINABILITY

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ABSTRACT

This article introduces a solitaire game for the classroom or personal use based on an adaptation of the States of Siege game engine used in many commercial wargames to model the global sustainability challenge of the 21st century.

The Earth systems are modeled by five variables (deforestation, ocean pollution, greenhouse gases, water scarcity, and soil degradation). These variables are impacted along the game due to population growth and consumption level growth. These impacts are countered by action units representing NGOs, regulation, R&D (technology), space resources (space), and governance (diplomacy).

The goal of the game is to limit the damage of the impacts so that the Earth systems don't enter a collapse. Civilization, as we know it, would come to an end, leading to a new dark age of hundreds or perhaps thousands of years. Instead, the aim is to achieve a new golden age of sustainable growth with a more manageable population level, new technologies, space resources, and prosperous global coordination.

It was designed for a two-hour session in a classroom or at home. Although designed as a solitaire game, it can be played in small groups of up to three students in a classroom.

The model simulates the challenges of increasing the population level during the 21st century, up to a forecasted 11 billion people, while increasing consumption levels to eradicate poverty and famine. This will generate several negative impacts on Earth systems with environmental and social consequences, limiting consumption growth itself. The way to mitigate those impacts and allow for a sustainable level of consumption is through the development of new technologies, obtaining access to space resources, and improving global governance through diplomacy.

The model is simple enough to give players a better view of the contradictions and solutions of this sustainability dilemma without entering too many calculations and statistics.

INTRODUCTION

This article introduces a solitaire game for the classroom or personal use, based on an adaptation of the States of Siege game engine used in many commercial wargames to model the global sustainability challenges of the 21st century. The game models Earth systems in terms of five variables (deforestation, ocean pollution, greenhouse gases, water scarcity, and soil degradation). These variables are modeled by levels of impact ranging from 1 to 11, and the greater the level, the bigger the degradation of that Earth system.

Throughout the game, these variables are impacted as the population grows to a forecasted 11 billion people, and global consumption levels also rise to eradicate poverty and famine. To control this impact and avoid Earth systems collapse, the player has to use action units, which represent NGOs, regulation, technology, space, and diplomacy. Not all of these are initially available, and they must be developed along the course of the game to improve their efficacy.

This simulates in a simple way the conflicts between environmental and social issues – the more we try to solve social problems, the more we create environmental ones. The solution to this dilemma is technology development, access to space resources, and global governance improvement. In this way, the game models go beyond the ESG framework (environmental, social, and governance), showing the conflict between the E and S in this framework, and that the solution must include technology and access to space resources. It could be argued that the game uses an ESGTS model, with the final TS standing for technology and space.

This game can serve as a basis for more complex simulations in the future, including two-player or multiplayer models, as well as for articles discussing how to solve the innate dilemma contained in the ESG framework and how to advance it. The game rules section was written as an appendix so that it can be printed separately for the player or students.

DESIGN GOALS

The main goal of the game is to serve as a solitaire game applicable in a classroom or at home with minimal infrastructure; therefore, it has a print-and-play logic. However, today we have ways to create virtual simulators like Vassal, or Tabletop Simulator, or even with PowerPoint, so that the main game doesn't necessarily have to be played with physical components.

The secondary goal is for it to be a challenging game to develop concepts such as population growth, consumption level growth, environmental impact, access to space resources, technology development, global governance, the ESG innate dilemma, and the ESGTS framework.

The tertiary goal is that it can be used in a two-hour session at home or in a classroom. This allows it to be applicable to executive education, MBA, EMBA, graduate, undergraduate courses, and high school.

The quaternary goal is for it to be fun and engaging while retaining a reasonable connection with the real world, so that the causal relations resemble the real world despite not being perfect models. The model is simple and explicit but close to reality. Dice are used to represent uncontrollable, life-like events such as technology development, diplomacy, weather, wars, and ecosystem collapses.

USAGE METHODOLOGY

This game was designed for use in a two-hour session, either at home or in a classroom. Although the game is intended for solo play, it can also be played in small groups of up to three students.

The only materials needed are printed copies of the rules, displays, and tables, along with at least two six-sided dice, and some plastic or wooden markers, or a pencil and an eraser. This makes it a low-cost application for any situation. A virtual version on Vassal, Tabletop Simulator, or PowerPoint can also be easily developed.

Preferably, the players should have received and read the rules beforehand, but this is not entirely necessary since the rules are simple and can be learned while playing.

In a classroom setting, the facilitator must divide the participants into groups, ideally groups of up to three students. The time usage should be as follows:

a) 5 to 10 minutes for group setup and game explanation.
b) 5 to 10 minutes for the first turn.
c) 2 to 5 minutes for subsequent turns.
d) 20 to 30 minutes for debriefing.

The facilitator should answer all questions pertaining to the rules of the game to the best of his or her ability but never directly answer questions about which strategy to pursue or what decision to make. If a group is stuck with decision paralysis, that is, they are unable to arrive at a decision, the facilitator should encourage them to make any decision just to break the paralysis.

Some questions and issues selected for discussion in the debriefing can be introduced to each group as they realize some of the points.

The model tends to lead to a defeat of the players in the last 10 turns. It's actually difficult to win the game. This is intentional and serves to create a challenging experience and invite players to replay the game.

There's no "safe" strategy, but developing technology first, then space, and lastly diplomacy is the logical strategy in development. Trying to reduce the bigger impacts initially is also a logical strategy to control them. If the global consumption level rises too high, it will create more problems but also tend to decrease on its own. It would probably reach level 4 and then gradually decrease, stabilizing at around level 3.

This is a psychologically tense game; even a victory will be very close to defeat. This intentional design aims to create a perception that overcoming this global sustainability challenge is not easy, mirroring a real-world issue.

DEBRIEFING

The game serves as a means to an end, which is learning through experience. To consolidate this learning, a debriefing is necessary at the end of the session. Although participants will probably keep talking about the game afterward, providing closure at the end of the session is essential.

The facilitator may discuss whatever he or she finds necessary and important given the purpose of the course, but some suggestions are offered:

a) The first question to address is the contradiction between social and environmental issues, that is while trying to eradicate poverty and famine, we increasingly pressure Earth systems. This is the ESG dilemma.
b) To resolve this dilemma, the game offers three lines of action. The first is the development of new technologies that can reduce environmental impact while creating jobs and increasing productivity. The second is the development of a space economy with asteroid mining, Space-based Solar power (SBSP), and orbital farming to alleviate the impact on Earth while increasing the resources available. The last is improving global collaboration, acknowledging the necessity of coopetition, global peace, and utopia. Collaboration can increase to a level where competition remains at a healthy level in terms of technology, economy, and exploration.
c) Another possibility is what the impact table really represents in terms of generated impacts. The deliberately abstract nature of the table avoids being specific about whether impacts were caused by wars, famine, pandemics, ecosystem collapse, overuse of agriculture, or reduced oil supply. This intention simplification aims to facilitate the game while leaving room for open discussion during debriefing.
d) Another discussion point can be the fact that the impact table assigns lowers numbers to indicate growth in the consumption level. While desirable from a social and economic perspective, this implies a modifier that will increase impacts in future turns, and that can lead a reduction in global consumption levels. The system is designed to stabilize this level at around level 3.
e) A potential discussion point is that the turn track table predefines the population level each turn. This is based on populational forecasts but can be debated, considering the peak may be lower at 10 billion or even higher in 12 billion. Which is the probable, or desired, balance between population, consumption, and environmental stress?
f) The best strategy for playing the game can be another avenue for conversation.
g) One last possibility is discussing the model's simplifications. While the model could be more complex in various ways, that would increase difficulty and playtime without much gain in pedagogical terms. The game, ultimately, serves as a means to an end.

COMMENTS

This model tries to simulate the sustainability dilemma in a simple and yet challenging way, allowing it to be played within a two-hour timeframe.

Several simplifications were implemented, and a simple game engine was chosen.

The *States of Siege* game engine, introduced by Victory point Games inc. (Levilof, 2008), proved to be so versatile and capable of including non-military aspects of conflict that it was adapted for various topics over the years. Currently, more than 30 commercial wargame titles use this game engine.

The adaptation involved eliminating the event cards and substituting them with a table (impact table). This not only reduces production costs, particularly for a print-and-play game, but also allows for a better understanding of the casual mechanism. Another important adaptation lies in the action units (not military units) representing ways to reduce and mitigate the damage to Earth systems. These units are not all initially available; players must develop those capabilities throughout the game. This approach is based on the RBV (Resource-Based View) theory of strategy (Penrose, 1959; Wernerfelt, 1984; Barney, 1991).

Since this is presented in a game format it naturally includes a Game-theory aspect to strategic theory (Fudenberg & Tirole, 1991). More specifically, decision-makers must make choices based on the probabilities of success and potential outcomes. They also need to think a few turns ahead in their plan, which is typical of strategic planning, as well as in many games (for example, chess).

The conflicting objectives of population growth, economic growth, consumption level, and sustainability are easily identifiable but often overlooked by authors. The game places this dilemma at the center of its model, emphasizing that technology and governance are the sole means to navigate this predicament.

Space exploration is imperative for accessing to new resources, a topic not extensively discussed. However, it becomes clear when investigating space program objectives geared toward achieving asteroid mining, Space-based Solar Power (SBSP), and orbital farming in the next decades.

In all three lines of development, the scale was chosen to be abstract to simplify the game. However, introducing novel technologies like a space elevator, fusion power, and synthetic photosynthesis could be considered. Nonetheless, this addition would create a debatable roadmap of development, potentially generating more noise and diverting the focus of the game from its central dilemma.

Finally, the five dimensions of the Earth systems were chosen to be representative, although not exhaustive. Deforestation, ocean pollution, and greenhouse gases primarily address environmental issues, while water scarcity and soil degradation pertain more to socio-economic concerns. This selection provides a relatively good overview without delving into discussions of resource depletion, ecological collapse, warfare, and economic inequality. The impact table is also intentionally designed in an abstract manner to avoid unnecessary debates regarding the specific causes of these effects.

These dimensions draw inspiration from the seventeen UN Sustainable Development Goals (2023) and the nine planetary boundaries outlined by the Stockholm Resilience Centre (2023). For example, UNDP Goal number 6 is centered around clean water and sanitation, correlating with Water scarcity (W) in the game model. Goal 15, which focuses on life on land, is represented by Deforestation (D) in the game model. Goal number 9, addressing industry, innovation, and infrastructure, constitutes a central aspect of developing capabilities in the game. In the nine planetary boundaries model, CO2 concentration relates to the Greenhouse gases (G) dimension of the game, while ocean acidification is associated with Ocean pollution (O).

Developing a two-player or multiplayer version of the game could be feasible using the Tragedy of the Commons as a theoretical basis (Hardin, 1968). In this case, several players would attempt to maximize their individual economic growth within a limited "common pasture," which is Earth. If all of them restrain their individual growth, the system is sustainable, but the game ends in a tie. This implies that all players have an incentive to maximize their economic growth. If only one player does so, the system remains sustainable, and that player wins the game. However, if all players simultaneously pursue maximum growth, the system becomes unsustainable and collapses, resulting in a loss for all participants. There is a psychological tension between the advantages of cooperating and competing simultaneously. However, developing, playing, and implementing such an adaptation in a classroom setting would be more complex. It could be considered as a potential future development in research.

CONCLUSIONS

This article introduces a solitaire game for classroom or personal use. It is based on an adaptation of the *States of Siege* game engine, designed to model the global sustainability challenge of the 21st century. The game is designed to last two hours and can be played either by oneself or in small groups. Its purpose is to create an affordable game that facilitates understanding of the central dilemma involving a growing population, the eradication of poverty and famine, and the simultaneous preservation of the environment. The game rules section is included in an appendix, allowing it to be printed separately for the participants.

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APPENDIX A
Game Rules

GAME SCENARIO

In the 21st century, Earth is under growing pressure due to population and consumption growth. The stress caused by the ever-growing demand for natural resources, industrialization, and consumption is leading to deforestation, greenhouse gas accumulation, ocean pollution, water scarcity, and soil degradation. Earth is under siege, and the global system may collapse later in the century. To control the damage and allow for the survival of the global system, it's necessary to develop new technologies, search space for new natural resources, and develop a global diplomatic pact of survival. This is a solitaire game in which your goal is to develop those fields while controlling and limiting the damage to Earth systems throughout the 21st century. You must avoid the collapse to win and save Earth.

COMPONENTS

Game components can be printed to play (print & play). Two six sided dice (2D6) are required, and plastic and wooden markers can be used to mark the various tracks.

Main display

This consists of five tracks representing the environmental and social status of Earth. Each track has a name, a letter in for referencing on tables, a number of boxes, and an indication of what each level represents in game terms. Those tracks are Deforestation (D), Greenhouse Gases (G), Ocean Pollution (O), Water scarcity (W), and Soil Degradation (S). All have nine boxes (or levels), with the exception of water scarcity that has 11 boxes (or levels).

- Deforestation (D) represents the percentage of forests lost in increments of 10%.
- Greenhouse Gasses (G) represents the increase in temperature compared to pre-industrial levels in steps of 0.25 C.
- Ocean Pollution (O) represents the percentage of ocean ecosystems degraded in increments of 10%.
- Water Scarcity (W) represents the population affected in terms of billions of people.
- Soil Degradation (S) represents the percentage of soil degraded for agricultural purposes in steps of 10%.

A white circle indicates the initial level on turn 1, and a black circle indicates the level at which the Earth systems collapse, and therefore the game ends in defeat for the player.

Action units

Fourteen action units are available to the player. These represent various organization types that can control the damage inflicted to Earth systems. Initially the player has only two of those (NGO's and Regulation) and can receive another three along the game (Technology, Space and Diplomacy). Each unit has a name and a number (that represents its strength). The action units of Technology, Space and Diplomacy have four different strength levels (1 to 4). Only one level is available to a player each time and represents the increasing efficacy of these units. It's recommended to print those and stick them to a thicker cardboard to facilitate their manipulation.

Turn track

This indicates the turn that the game is currently in. Each turn represents five years from 2011 to 2100. The blue circle designates turn 1, where the game starts. Each box has a population value (Pop) in billions, referring to the column in the impact table where the player will roll the impact for that turn. This population value starts at 7 (billions), increases to 11 (billions), and then decreases to 10 (Billions). These values are based on real-world population forecasts. Players should use a plastic or wooden marker to indicate in the current turn in the game or mark it with a pencil.

Development display track

This indicates the level of global development in three separate fields: technology, space, and diplomacy. In all fields, the initial level of development begins in "Box 1," as indicated by the white circles. When the development level reaches "Box 2," the player receives a new action unit with strength 1. As shown in the display, when the level of development reaches a new even

level, that action unit is upgraded to a new strength level. Remove the current unit in use and substitute it with the new upgraded action unit. On the right side, indicated in a hexagon, is the necessary number to be rolled on a six-sided die (1D6) to increase the development level during the development phase. Players can use a plastic or wooden marker to indicate the level for each track or mark it with a pencil.

Impact table

This table is used to determine the impact on the Earth systems during each turn in the impact phase. It consists of five columns, each representing a different population level (7, 8, 9, 10, and 11), as indicated in the turn track. The table yields a number of impacts (1 to 4), highlighted in black (D, G, O, W, and S). For each impact noted in the table, the corresponding impact level is increased by one box in the main display. Additionally, the result may include a number (+1 or -1), indicating the change in the Global Consumption Level table & track.

Global consumption level table & track

This table serves as a track and indicates the current global consumption level on a scale from 1 to 6. The initial level is 1, and it can fluctuate both upward and downward based on the result obtained each turn during the impact phase on the impact table. The 'Mod' (Modifier) column indicates the number to be added to the dice when rolling on the impact table. The greater the global consumption level, the higher the impact on Earth systems will be on the main display. The last column is purely decorative but represents the equivalent level of consumption in 2021 for debriefing purposes.

Six-sided dice (1D6)

The game requires at least two six-sided dice with faces numbered from 1 to 6. These can be easily obtained from other games or at a game store.

Markers

It is recommended that players use plastic or wooden markers for general use in the game. These can be found in other games or bought at gaming stores. However, these markers are not absolutely necessary and can be substituted with a pencil.

GAME OBJECTIVE

The player represents an abstraction of all human societies, or Mankind if you prefer. The objective is to prevent any of the tracks in the main display from reaching a maximum level, as indicated by red circles. If, during the impact phase of any of the eighteen turns, any of the tracks reach the maximum level, then the game ends in defeat for the player. This implies that Earth systems collapsed, and civilization as we know it also collapses. It will take hundreds, or perhaps thousands of years, to recover.

If the player manages to avoid that by the end of turn eighteen, they win. Mankind has succeeded in averting Earth systems collapse, and the population will now subside to a more manageable level, thanks to new technologies, space resources, and diplomatic collaboration.

GAME SEQUENCE

The game consists of eighteen turns, each further divided into distinct phases:
Phase 1 – Impact phase
Phase 2 – Action phase
Phase 3 – Development Phase
Phase 4 – End of turn Phase

Here are the details of each phase.

Phase 1 – Impact Phase

During this phase, the player consults the turn track to determine the table for rolling, depending on the population level (7, 8, 9, 10, or 11 Billion). Additionally, the player must refer to the Global Consumption Level table & track to obtain the modifier (mod) based on the current consumption level (0 to +5).

Next, the player rolls two six-sided dice and adds the modifier (2D6 + mod). The player then cross-indexes this result in the impact table to obtain the result.

The result will indicate which track on the main display advances one box. It can yield one to four results, denoted by a black letter (D, G, O, W and S). It will also specify whether the global consumption level will increase (**+1**) or decrease (**-1**). Players need to adjust all tracks immediately according to the result. If any track on the main display reaches the maximum level, as indicated by a red circle, the game immediately ends in defeat for the player.

Phase 2 – Action phase

In this phase, the player decides how to allocate the action units. The player must choose which tracks to allocate each of their action units to in order to reduce the level of damage to Earth systems. It's possible to allocate more than one unit to the same track.

After allocating the units, the player must roll one six-sided die (1D6) for each unit. If the number rolled is equal to or smaller than the strength of the unit, then that level of impact is reduced by one box, meaning it moves one box to the left.

For example, let's consider two units of strength 2 allocated to Deforestation (D). If one obtains a die result of 2 and the other obtains 4, in this case, the deforestation level is reduced by one box or level. If both units obtained a result of 2 or less, then the deforestation level would be reduced by two boxes, or levels.

Phase 3 – Development phase

In this phase, the player chooses which area to develop, selecting between R&D (Technology), Space resources (Space), or Governance (Diplomacy).

The initial development level starts in box 1, as indicated by white circles. Each area is measured separately on the tracks, and the scale is abstract.

After choosing the area to be developed, the player rolls one six-sided die (1D6) and compares it to the necessary roll. For R&D, the player needs 3 or more; for space resources, 4 or more; and for governance, 5 or more.

In case of success, the player advances the development level by one box. When the development level reaches box 2, a new action unit at strength 1 is received by the player. When the development level reaches any even level, the corresponding action unit is upgraded to a new level. Remove the current unit and replace it with the upgraded one.

The names and strengths of the new and upgraded action units are shown in the display.

Phase 4 – End of Turn phase

In this phase, the player advances the turn track marker to the next box.

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EXHIBIT 1
Main Display

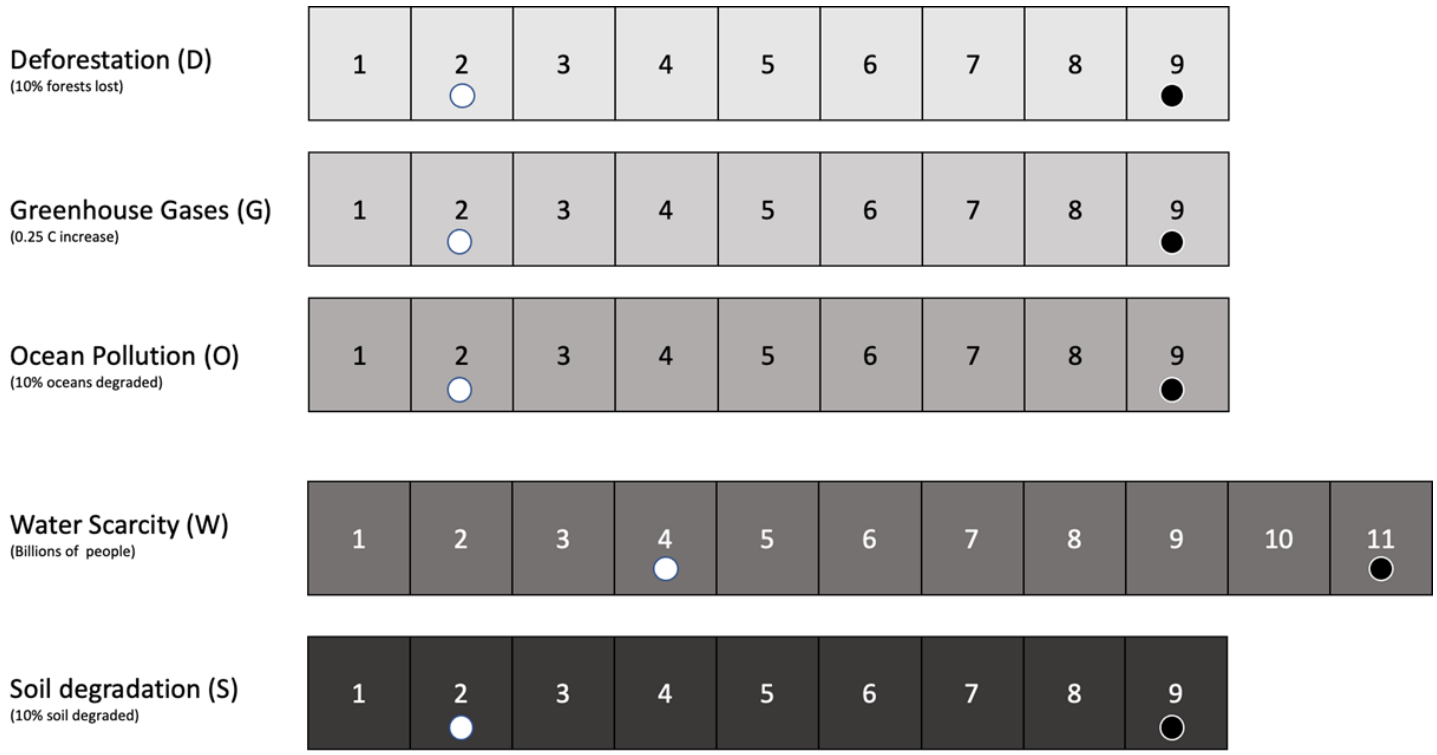

EXHIBIT 2
Action Units

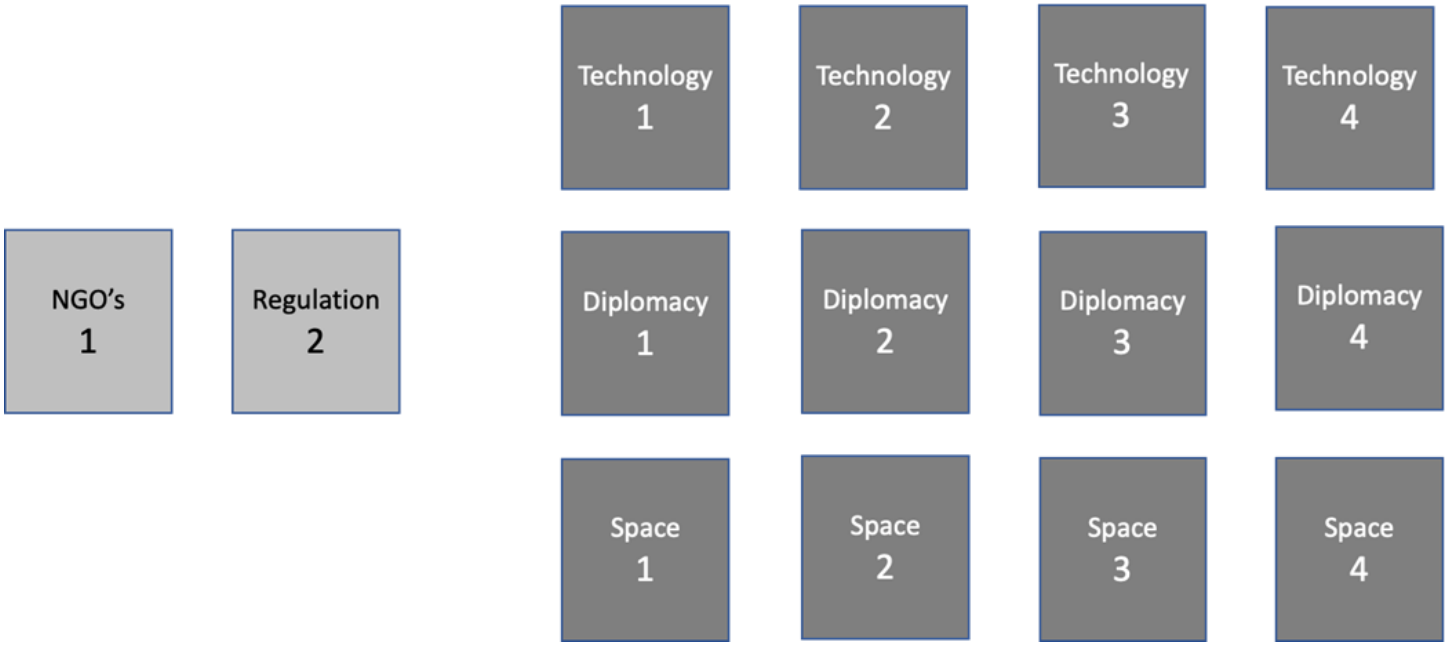

EXHIBIT 3
Turn Track

Turn 1 ○	Turn 2	Turn 3	Turn 4	Turn 5	Turn 6	Turn 7	Turn 8	Turn 9
2011-2015	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	2051-2055
Pop **7 billions**	Pop **7 Billions**	Pop **8 Billions**	Pop **8 Billions**	Pop **9 Billions**	Pop **9 Billions**	Pop **9 Billions**	Pop **9 Billions**	Pop **10 Billions**

Turn 10	Turn 11	Turn 12	Turn 13	Turn 14	Turn 15	Turn 16	Turn 17	Turn 18
2056-2060	2061-2065	2066-2070	2071-2075	2076-2080	2081-2085	2086-2090	2091-2095	2096-2100
Pop **10 billions**	Pop **10 Billions**	Pop **10 Billions**	Pop **11 Billions**	Pop **11 Billions**	Pop **11 Billions**	Pop **11 Billions**	Pop **10 Billions**	Pop **10 Billions**

EXHIBIT 4
Development display track

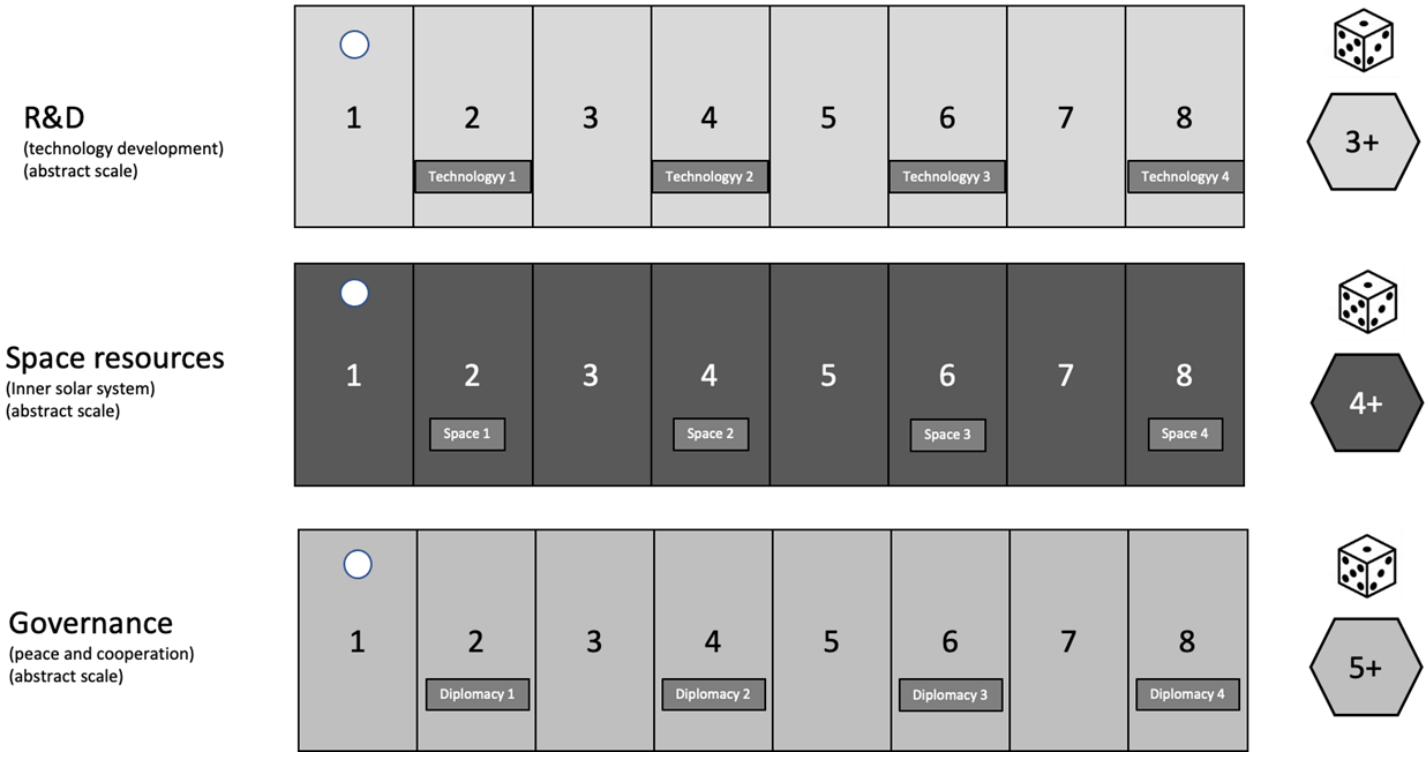

EXHIBIT 5
Impact Table

Dice (2D6+mod)	7 billions	8 billions	9 Billions	10 billions	11 Billions
2	D +1	G +1	O +1	W +1	S +1
3	G +1	O +1	W +1	S +1	DG +1
4	O +1	W +1	S +1	DG +1	GO +1
5	W +1	S +1	DG +1	GO +1	OW +1
6	S +1	DG +1	GO +1	OW +1	WS +1
7	DG	GO	OW	WS	SD
8	GO	OW	WS	SD	DGO
9	OW	WS	SD	DGO	GOW
10	WS	SD	DGO	GOW	OWS
11	SD	DGO	GOW	OWS	WSD
12	DGO	GOW	OWS	WSD	SDG
13	GOW -1	OWS -1	WSD -1	SDG -1	DGOW -1
14	OWS -1	WSD -1	SDG -1	DGOW -1	GOWS -1
15	WSD -1	SDG -1	DGOW -1	GOWS -1	OWSD -1
16	SDG -1	DGOW -1	GOWS -1	OWSD -1	WSDG -1
17	DGOW -1	GOWS -1	OWSD -1	WSDG -1	SDGO -1

EXHIBIT 6
Global consumption level table & track

Level	Mod	Country (2021 Level)
1 ◯	+0	Indonesia
2	+1	China
3	+2	Poland
4	+3	Germany
5	+4	USA
6	+5	Switzerland