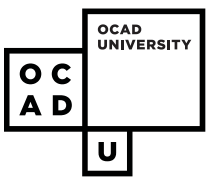
How mutable is the future:

Can long futures be adaptively transformed by choices and decisions in the face of indomitable challenges?

by
Adam Oliveira | Navinder Matharu



Submitted to OCAD University in partial fulfillment of the requirements for the degree of **Master of Design** in **Strategic Foresight and Innovation**, Toronto, Ontario, Canada, 2019.

STOCK ICONS AND IMAGES
www.freepik.com
www.flaticon.com
www.shutterstock.com

NASA PUBLIC DOMAIN IMAGES
images.nasa.gov

MEDIA LINKS

QR codes have been provided for easy linking to related digital media. Position your smartphone or tablet using the Camera app over the QR code, then tap the link that appears.

STATEMENT OF CONTRIBUTIONS

This joint research project, including the invention of the board game, has been a full collaboration between the authors.

Contents

Abstract · **5**
Introduction · **6**
Research problem · **13**
Framework · **15**
Methodology · **28**
Discussion · **46**
Bibliography · **52**

Figures

1. Moonwatch · **7**
2. Models of time · **8**
3. Synthesis map · **10–11**
4. RSD poster · **12**
5. Dimensions of change · **13**
6. Value proposition canvas · **15**
7. Project timeline · **17**
8. Building a colony · **18**
9. 4 futures · **22**
10. Generating situations on Mars · **25**
11. v1 situations · **26**
12. v1 play test · **27**
13. Play testing · **28**
14. EventBrite registration · **32**
15. Social media · **32**
16. Project blog · **33**
17. Communicatiomn · **33**
18. Capturing video and audio · **34**
19. Mobile capture form · **34**
20. Tracking tool · **35**
21. Transformational score · **35**
22. End of session #1 · **36**
23. Session #1 future trajectories · **36**
24. End of session #2 · **38**
25. Session #2 future trajectories · **38**
26. End of session #3 · **40**
27. Session #3 future trajectories · **42**
28. Session #1 wordcloud · **44**
29. Session #2 wordcloud · **44**
30. Session #3 wordcloud · **44**
31. Combined wordcloud · **45**
32. One small step · **46**
33. Strategic options · **49**

Tables

1. Observable inputs · **14**
2. Jobs, pains, and gains · **16**
3. Differentiators · **16**
4. Calculating velocity · **18**
5. Calculating amplitude · **18**
6. Turn activities · **19**
7. Co-dependent forces · **19**
8. Living tiles · **20**
9. Uncertainties and situations · **20**
10. Stacking resources · **20**
11. Hotelling's game · **24**
12. REB approval · **30**
13. Play session agenda · **30**
14. Play session overviews · **31**
15. Session #1 codified data · **37**
16. Session #2 codified data · **39**
17. Session #3 codified data · **41**
18. Semantic lexicon · **43**
19. Mass market board game · **48**
20. Expanded game system · **50**
21. Niche evaluation tool · **50**
22. Engagement offering · **50**

Abstract

An earlier inquiry and exploration into the systems involved in large scale space travel revealed a compelling narrative of balancing forces and influences, which were later combined with strategy and game theory, and designed into a cooperative multiplayer board game. Evaluations (playtests) of a prototype board-based game revealed several intriguing dynamics affecting the probabilities of complex futures, one of which suggested that futures are not the outcomes of planned trajectories, but are continuously changing possibilities over time, capable of moving between directional dynamics such as continuation, discipline, collapse, and transformation. Player motivations, interactions, decisions, and actions, both initiated or in response to events, were the primary authors of a game's progression. This research project further investigates the influence of active intervention into future outcomes by explicitly incorporating critical uncertainties into an updated version of the board game. Using the updated game as a framework for interaction, the project collects data from Design Action Research workshops to discover a rubric effective for measuring patterns of change based on the Dator 4 Futures framework.

KEY WORDS

futures, strategic foresight, motivations, interaction, decisions, critical uncertainties, space travel, games, Mars, space colonization, systemic design.

ACKNOWLEDGEMENTS

We would like to acknowledge Dr. Peter Jones, Dr. Erick Dupuis, and Ben Feist for their invaluable domain insight and advice to this project.


OMEGA
Speedmaster
PROFESSIONAL
60
40
20
20
10
12
9
3
6

Introduction

Science fiction is littered with hundreds of short stories, novellas, and novels dealing with protagonists against fatalist futures. They express our fascination with time-travel, and our predilection for altering its trajectory. Despite marvelous feats of human ingenuity over fate, such as the Moon landing or Apollo 13 (Krantz, 2001), outside of fiction, the notion of a mutable future—one that continuously oscillates between collapse, continuation, discipline, and transformation, and maybe all of these at the same time, in reaction to our present actions—has lacked serious discussion (Todd, 2016). Religion, philosophy, and science, all describe some version of the "Box Universe" (Einstein, 1917), in which time is a static dimension where events in the future are as fixed to temporal coordinates as those in the past. We merely experience them as we would objects while traversing through a landscape. Even our methods in strategic foresight portray each version of the future in its own sandbox, distinct and exclusive from each other. The fatalist future has been so deeply baked into our world views by our religious roots (Greach, 1971) that Einstein famously said, "God doesn't play dice with the Universe," when he challenged concepts of uncertainty and probability (Heisenberg, 1949) in quantum mechanics that violate precepts of divine design. Time, in the quantum model (Moyer 2015), exists both as a wave of possibilities and definitively observed events. Controversy lies in the implication that the observer decides which future emerges, and through intervention, can assume an active role in authoring it. Michael Valentine Smith's declaration, "I am God" in Stranger In A Strange Land (Heinlein, 1961) was not defiant, but an embrace—a grokking—of this role's responsibility for having agency over our fate, and to veer it from the version many experts currently regard as catastrophic and approaching fast.

This is ontologically a design-oriented inquiry (Escobar, 2012; Winograd and Flores, 1986): Are we doomed? Or can we design our way to a better future?

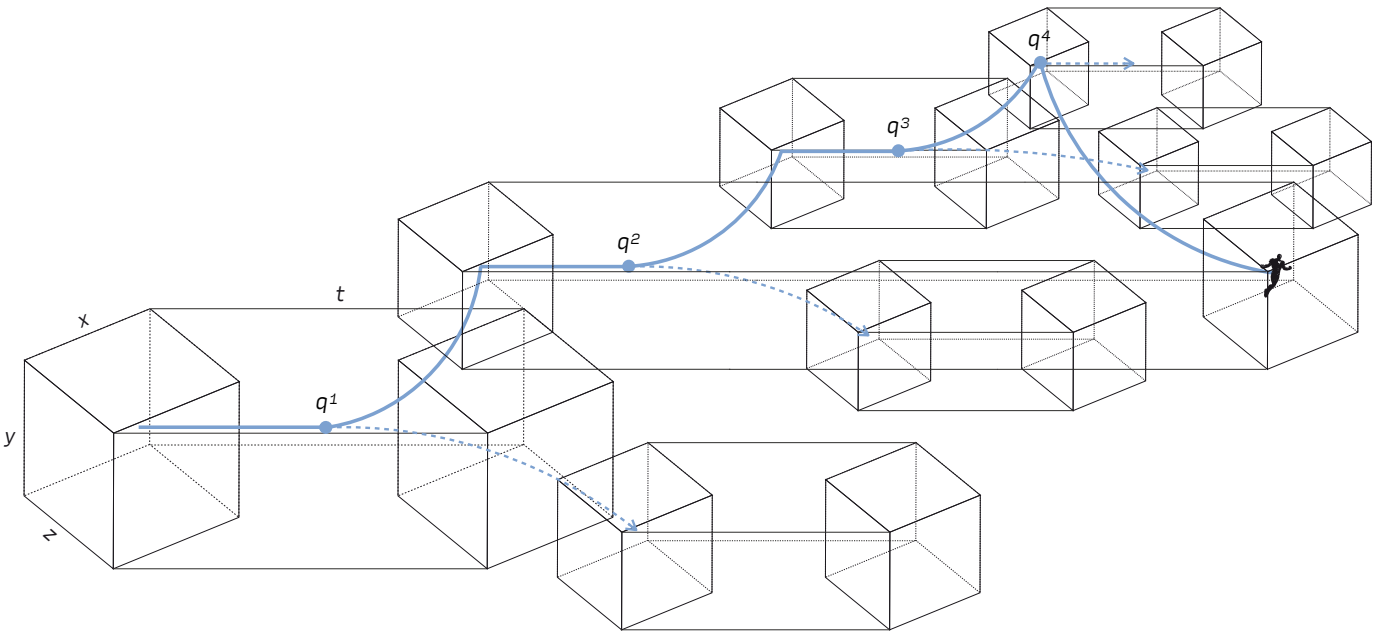
By ascribing "design" to this inquiry, we mean to differentiate it from philosophical or fantastic imagining. The activity of design is intentional and purposeful, and aims to devise implementable and measurable proposals

←
Fig 1. Moonwatch: Photo of Adam's personal Omega Speedmaster Professional, reference 3750.50, a metaphor for human ingenuity over space and time. This watch's significance to NASA began when Wally Schirra wore his Speedmaster reference CK2998 during the Mercury–Atlas 8 spaceflight in 1962, completing six orbits around the Earth. Buzz Aldrin wore his reference ST105.012 on Apollo 11 that landed on the Moon, which is where this watch gets its beloved nickname. However the story that cemented the history of the Speedmaster is its use for timing the critical 14 second burn by James Lovell during Apollo 13's re–entry after the spacecraft's onboard instruments failed. To date, it remains the only mechanical timepiece qualified by NASA for all manned space missions.

under real-world constraints, requiring considered compromises, for the sake of targeted outcomes. It brings it back from an intellectual domain and makes it familiar at a practical level. Can we design a better future for a product such as bicycle? Can we design a better career for an early stage professional, or redesign one at a late stage? Can we design a better 5 year strategy for a startup? Can we design a better way to generate energy, produce food, and cure diseases? Although the inquiry becomes increasingly complex with scope, fundamentally it asks whether our efforts at affecting change have an observable pay-off.

This question is fairly easy to measure on a material basis. A bicycle's success is demonstrated through sales, drag coefficient, speed and acceleration, comfort, weight, and appearance, and we can easily deconstruct it to make decisions for gains in some areas at the cost of others. For example, we can design a faster bike by increasing the rigidity of the frame at the cost of a harder, less comfortable ride. These are relatively benign compromises. However, it gets more complicated with social systems. An organization's health involves many immaterial aspects that are not simply captured by a balance sheet. Happiness, productivity, longevity, sustainability, and morality, are some of the dimensions in motion, and decisions that transform some come at serious costs to others. When we expand our boundaries further, and consider the advancement of our species, the stakes become even more complex. We can repair the environment by breaking the economy. We can elevate individual liberty by forfeiting state provision and security. Despite scope and complexity though, the basic principles are still the same—there can never be a single perfect outcome, because intent and compromise determine the observer's measurement of successes and failures. At any given moment, a snapshot of the human condition will reveal it to be remarkably transformational by some measurements, and terribly disastrous by others. Yet over time, as intent and compromise change, and transformation to some parts avert demise by extending opportunities to other parts, we see multidimensional polyrhythmic trajectories emerge. Although never perfect, the data in the patterns show historically, in many cases, undeniable progress (Pinker, 2018) despite how the world has been ending for one reason or another for a very long time. Dare we attribute this overall progress to intentional design?

To test the effect of design interventions on large-scale systems over long time-periods, we needed an interactive model that could compress their complexity and continuity into a small format. In an earlier Systemic Design project, we explored the forces of large-scale systems crucial for commercial space travel to Mars, which were synthesized into a visual narrative. It identified and defined foundational concepts including the co-dependency of Scientific, Commercial, Military, and Civil-



ian powers, and four stages of progression from Essential to Transformation. Although thematically speculative, it was an attempt to deconstruct and blueprint the mechanics of advancement in our own social system. We then activated this in a subsequent Independent Study project by combining it with strategy and game theory, and reimagining it as a board game. The initial version (v1.0) of the game incorporated additional concepts for progression, or a forward movement of events over time, including coopetition, stocks-and-flows of resources, absorptive capacity, and disruptions. After we play-tested this version, we realized we had the basis of an interactive model that could simulate the mechanics and measure, at least primitively, organizational potential for transformation. An updated iteration (v2.0) of the game evolved out of this as a result, and became the Design Action Research (Jones and Swann, 2002) framework for this project. Using this framework, we captured turn-by-turn metrics from three play sessions, and derived a preliminary rubric suggesting the "shape" of each group's simulated future. Our objective was to examine whether games progressed according to players' intended design in opposition to disruption—in the form of time pressure, external threats, and competition—through qualities such as adhesion, resilience, and adaptation.

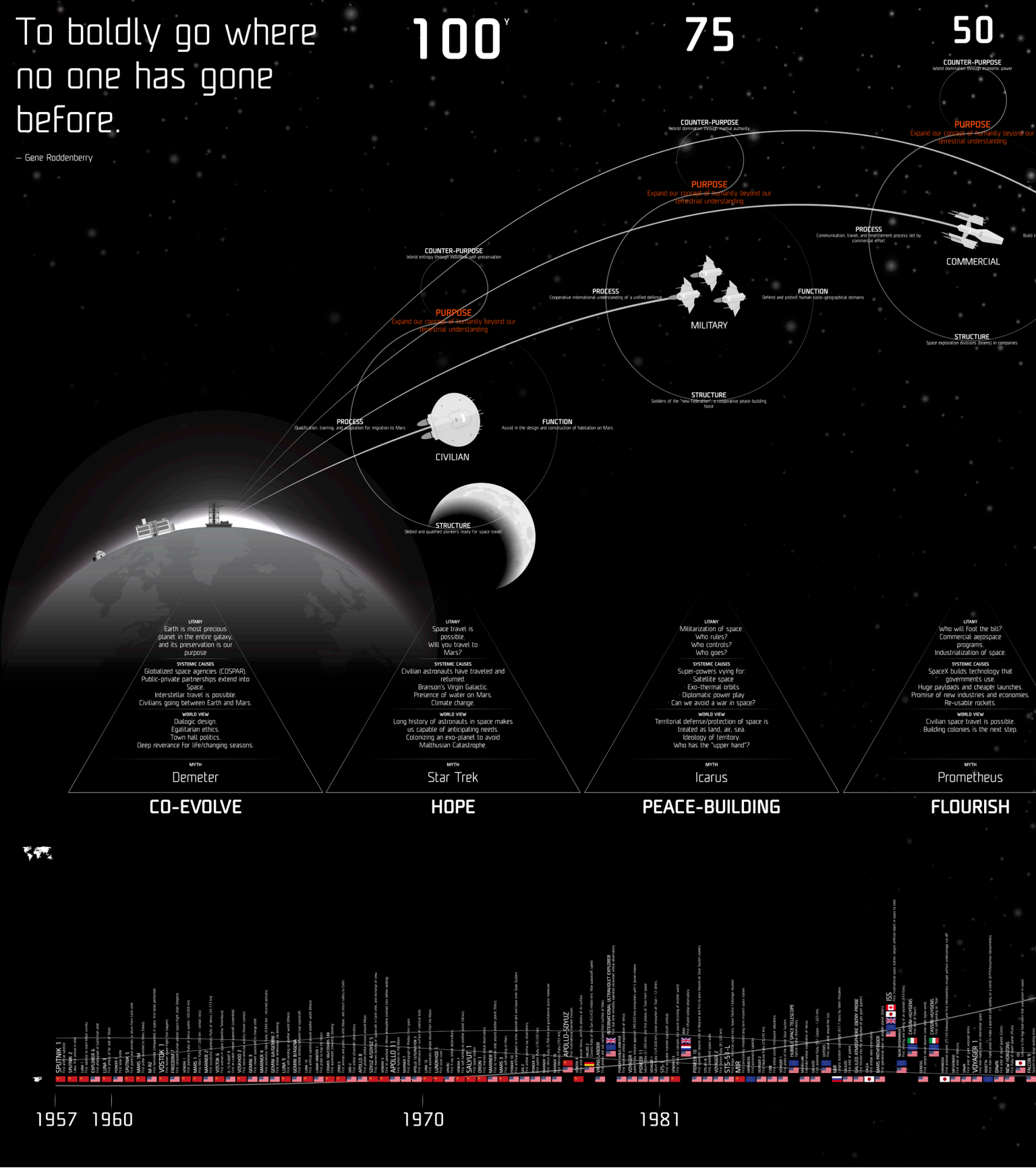
We must acknowledge however that all games operate within their own bounded rationality (Simon, 1991), and as such players' actions and outcomes must be taken figuratively. Use of our framework does not, nor claims to, predict the future. However, in the absence of a functioning time machine, it provides an environment for players to exercise design and foresight oriented strategic thinking on high-stakes systems, and explore their effects on futures together, either cooperatively or competitively. It is, we hope, a type of game that can "make the world better" (McGonigal, 2010), and therefore of considerable interest to us that it offers value beyond our use of it for this inquiry. Given the game's ability to scale and extend to different themes and premises, such as situations and uncertainties compatible with NASA's 2024 commercial lunar missions (https://www.nasa.gov/specials/apollo50th/back.html) which can augment early candidate selection, fields such as education, enterprise strategy, and industry foresight may benefit from an interactive framework capable of dynamically testing organizational decision-making as it applies to transformational initiatives.

←
Fig 2. Models of time: Our three-dimensions of space (*x*, *y*, and *z*) and the dimension of Time (t) are connected as a "Block Universe" (Einstein, 1917), implying that events are fixed in space and time.

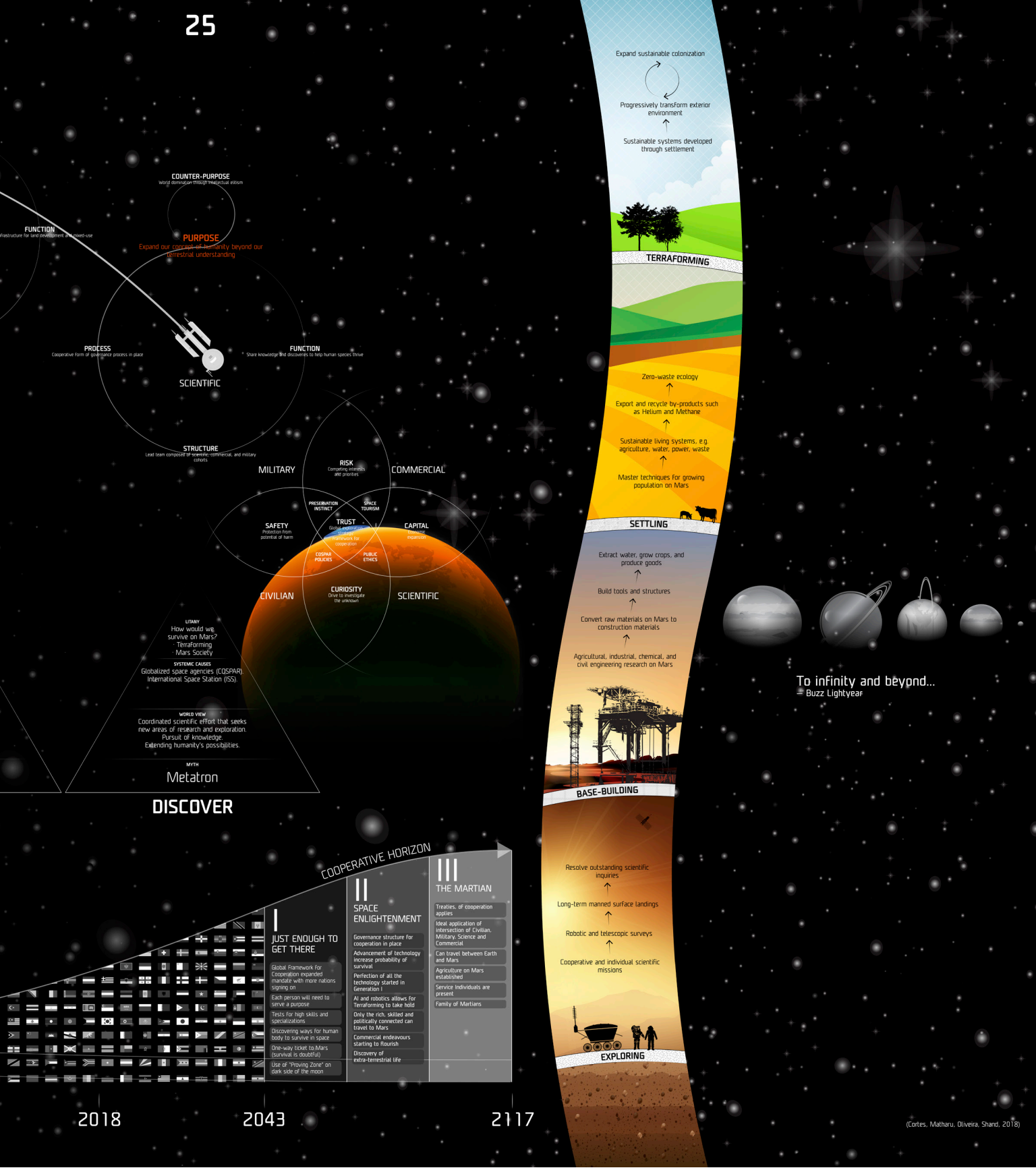
However, quantum mechanics introduces uncertainty and probability into the model of time (Moyer, 2015) where all possible timelines (q^x) of any uncertainty simultaneously exist, and only when observed do we determine which timeline is perceived as real. This suggests that decision has a role here.

To boldly go where no one has gone before.

— Gene Roddenberry



↑
Fig 3. Synthesis map: Exploring co-dependent forces in the advancement of commercial extraterrestrial colonization.



An animated exegesis of the synthesis map.

Watch the video»

Interstellar

“To Boldly Go Where No One Has Gone Before”

A. Oliveira, I. Cortes, L. Shand, N. Matharu

RS D7 2018

A game of coopetition

The intrinsic human need to explore, discover, and conquer new frontiers saturates every domain, from sports to science. By far the most daunting of these domains, whether material, physiological, or intellectual, is interstellar space. Although still at least 100 years away from viable commercial space travel to Mars, the entities with the means to drive this pursuit remain vigilant despite popular wisdom. It is a pursuit that requires a non-zero-sum game, a Systems Thinking perspective of global cooperation and mutual gain. Technology, policy, and social advancements born out of space travel may provide the answers to some of Earth’s most pressing problems. The challenge has been to inspire the vast majority of people to look upwards again after decades of fixation on the current world condition. Media and entertainment play significant roles in influencing attitudes and world views, and games in particular can offer ways to explore complex multidimensional ideas in simple and fun ways. By combining gaming and systems concepts, Interstellar, explores the social and ethical plateaus that challenge our evolution toward a unified space-going species through a compelling multiplayer board game. By balancing the causal, and contradictory, relationships between military, civilian, commercial and scientific interests, the game lets players explore the dynamics between cooperation vs competition, and their effects on advancing civilization into Space.

Fig. 2 Play-testing a prototype of the board game designed to interactively explore the concepts in the sythesis map.

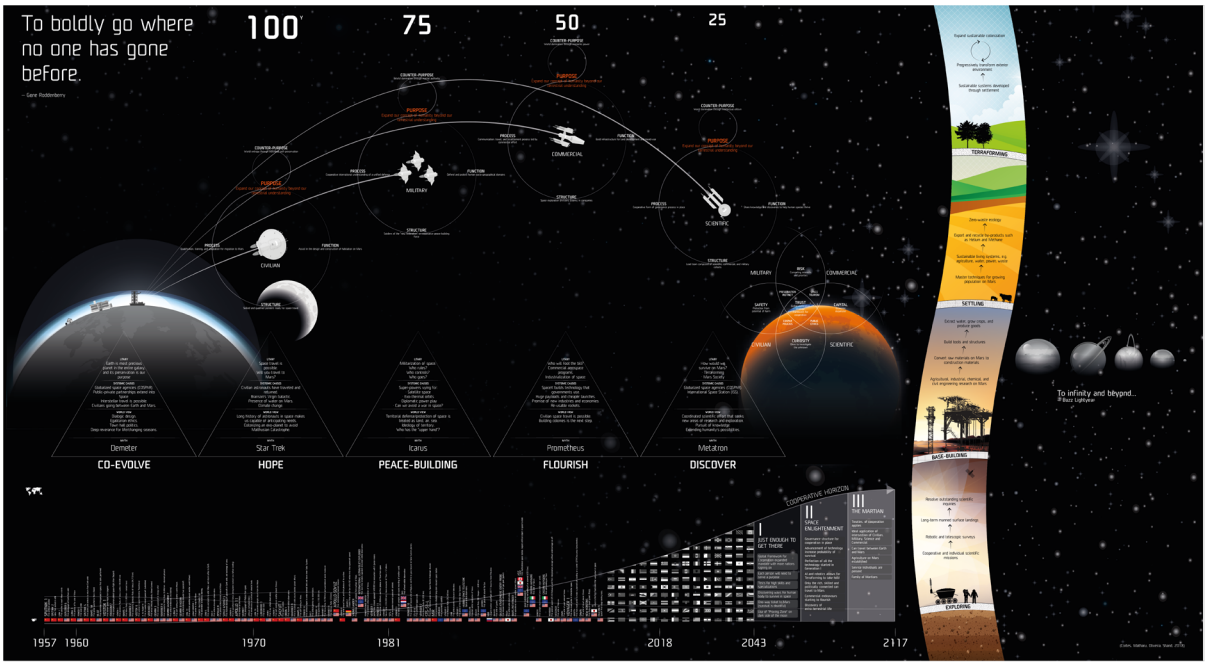
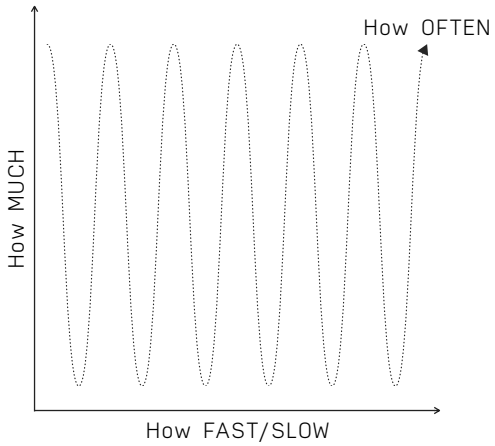


Fig. 1 Our 100 year journey to Mars requires “coopetition” and trust—it is a social challenge rather than a technological one.

Research problem

Having established a design ontology for mutable futures in the Introduction, we can now further define the specific questions that compose our inquiry. In order to test if *long futures can be adaptively transformed by choices and decisions in the face of indomitable challenges*, we needed to be able to propose a form of measurement that could be applied to the archetypal trajectories of 4 Futures (Dator, 2009). Since we posit that advancement in complex systems is multidimensional, with different parts on simultaneous trajectories, our research has attempted to quantify HOW MUCH (*amplitude*), HOW FAST or SLOW (*velocity*), and HOW OFTEN (*inflection*) these trajectories change in response to intervention, and if they develop toward equifinality or multifinality (Almy & Cicchetti, 2018), i.e. if all parts eventually converge toward a common future, or if they perpetually maintain multidimensionality.

←
Fig 4. RSD7 poster: Synthesis map combined with v1.0 of the board game was selected for exhibit at RSD7 in Turin, Italy, Oct 2018.



→
Fig 5. Dimensions of change: How MUCH (*amplitude*), how FAST/SLOW (*velocity*), and how OFTEN (*inflection*), are dimensions we measured to visualize each future trajectory.

The entire realm this inquiry offers is massive, and would require more than several studies for a full investigation. We have consequently bounded the scope of this project to discovering a preliminary measurement structure that could be used to suggest the potential transformational characteristics of a team or organization, which may imply value in contexts such as enterprise strategy and mission-critical planning.

We identified five (5) observable inputs that informed our rubric for future mutability:

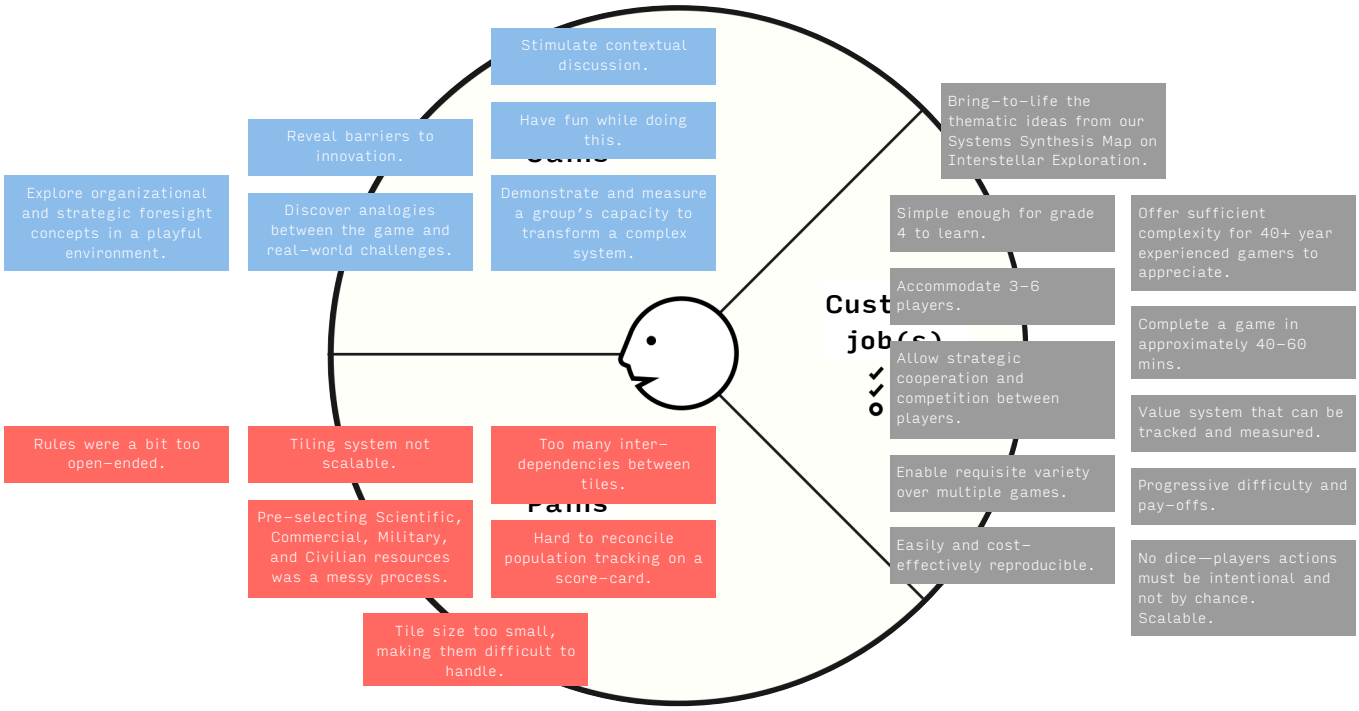
Table 1. Observable inputs

1	What are the costs and pay-offs of decisions, initiated and in response to events, that trigger change to the current trajectory of our future?
2	How does the decision making process between individuals and groups affect the velocity of transformation?
3	Do cognitive biases in decision-making always produce inferior outcomes or can they yield successful change?
4	Does progression in a type of future reach an inflection point-of-no-return or does it remain perpetually mutable?
5	If critical uncertainties propose branches in futures, can these branches be used to intentionally steer our trajectory?

Framework

We have *designed* a board game *system* themed around interstellar colonization that is a model for exercising cooperative *strategic foresight* on mutable futures. Using the game as a tool for interaction in Design Action Research , we collected data from 3 play sessions to codify into a rubric for measuring an organization's capacity to transform and overcome barriers to *innovation*.

↓
Fig 6. Value proposition canvas: Using Design Thinking to define value–based criterial.



Design criteria

Based on what we learned from play tests we conducted in summer 2018 for version 1.0 of the game, we set a number of criteria for version 2.0 to improve on deficiencies and integrate new mechanisms that would allow us to measure data we needed for this study. Using a Value Proposition Canvas (Osterwalder, 2014), we captured what the game would need in order to be minimally viable.

Table 2. Jobs, pains, and gains

JOBS-TO-BE-DONE	
• Bring-to-life the thematic ideas from our systems synthesis map on Interstellar Exploration. • Simple enough for grade 4 to learn. • Offer sufficient complexity for 40+ year experienced gamers to appreciate. • Accommodate 3–6 players. • Complete a game in approximately 40–60 mins. • Allow strategic cooperation and competition between players. • Enable requisite variety over multiple games. • Progressive difficulty and pay-offs. • Value system that can be tracked and measured. • No dice—players actions must be intentional and not by chance. • Scalable. • Easily and cost-effectively reproducible.	
PAINS (from v1.0)	**GAINS**
• Tile size too small, making them difficult to handle. • Pre-selecting Scientific, Commercial, Military, and Civilian resources was a messy process. • Hard to reconcile population tracking on a scorecard. • Too many interdependencies between tiles. • Tiling system not scalable. • Rules were a bit too open-ended.	• Explore organizational and strategic foresight concepts in a playful environment. • Discover analogies between the game and real-world challenges. • Demonstrate and measure a group's capacity to transform a complex system. • Reveal barriers to innovation. • Stimulate contextual discussion. • Have fun while doing this.

Key criteria

Although the board game is themed around interstellar colonization, the systems ideas and concepts translated from our synthesis map reflect broader evolutionary questions and paradigms common to many levels of our social system. At a macro level, it examines our role in ecology, and the many epic challenges we face that threaten our extinction. At an intermediary level, the game's constructs examine enterprise organizational strategy in a rapidly changing economy driven by tremendous market forces. At a micro level, it offers a framework for exploring small team and leadership ability to mobilize strategy and affect systemic change. As such, the game's design needed to offer sufficient opportunity for the simulation and scenarios to be abstracted at different levels, from very literal to analogous.

Given that the game will be used as a tool in Design Action Research for collecting data, it also needed to have mechanisms we could quantify, particularly metrics that allowed us to mathematically determine several dimensions of transformational capacity. It was important for this study not only to rely on qualitative data, since empirical measurement would provide significantly stronger validation for our conjectural theories.

Learnability was a high priority as the participants in our play sessions would be only playing the game for the first time, possibly only once, and would be constrained by the time window of the session. This meant simplifying aspects of version 1.0, which included minimizing the number of "moving parts" and making things bigger. The pattern language we designed for the Tile system, the Resource system for stocks-and-flows, and the scoring system for determining risk and pay-off, all needed to be overhauled.

Finally, we needed the game to be scalable. Although this version had to be viable enough for us to conduct our research, we also envision commercial opportunities to publish it to a wider audience. Our criteria for scalability meant the game system could be modularly extended through expansion packs, e.g. "Alien Invasion" pack, "Civil War" pack, "Biological Outbreak" pack, etc., which would keep the play experience evergreen.

Table 3. Differentiators

Differentiating features
• Players play each turn simultaneously. • 3 modes of play. • Cooperative strategy. • Build vertically as well as laterally. • Uncertainties challenge players with two opposing strategic options.

Design process

A journal documenting the design iteration process and early play-tests has been published on our blog cosmiclabs.ca. To produce a play-ready high-fidelity prototype, our critical path involved the following milestones:

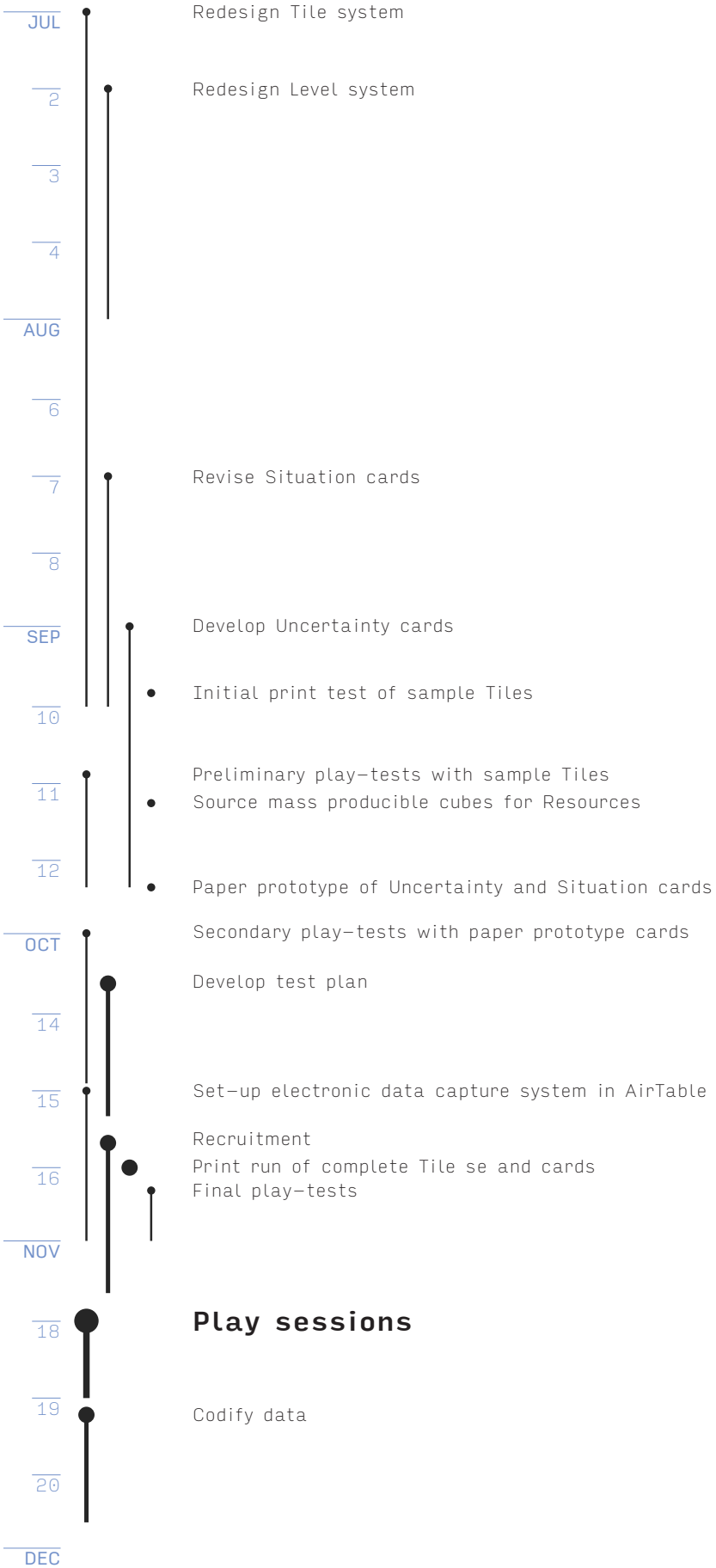
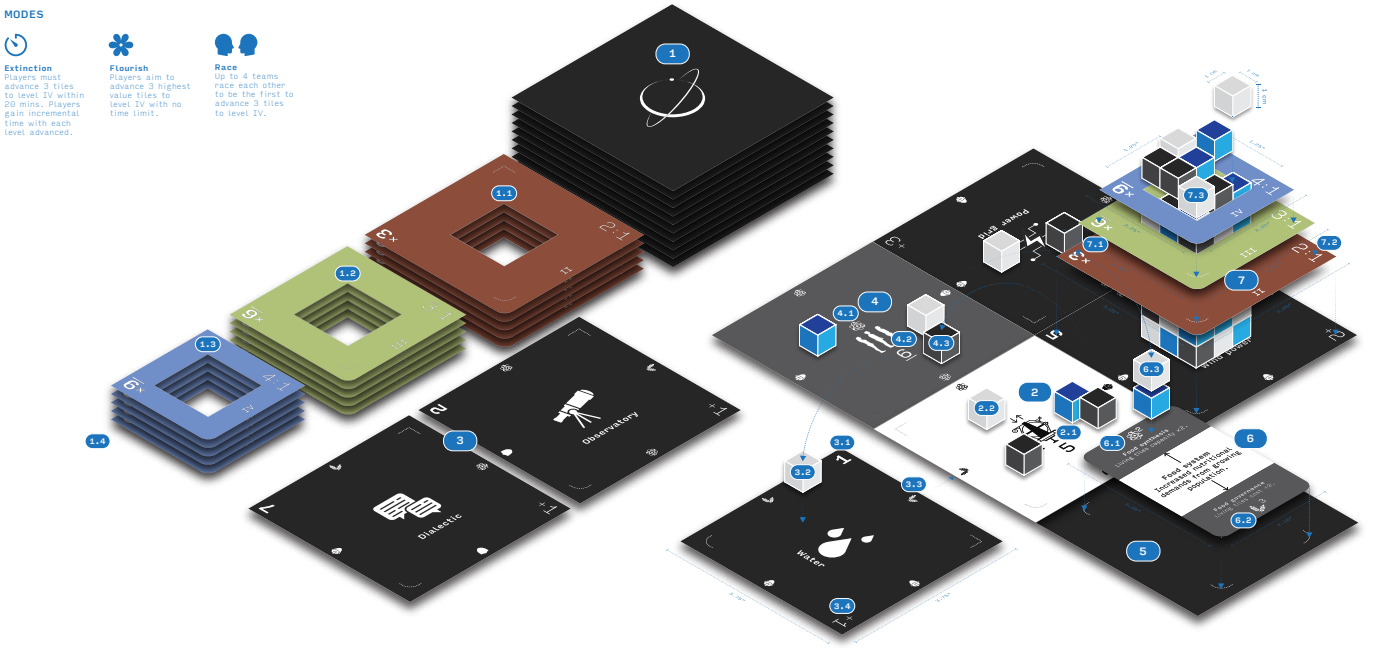


Fig 7. Project timeline: Week–by–week breakdown of critical milestones.

Project blog: To explore our journal updates, photos, play tests, and supporting media, visit our blog at cosmiclabs.ca »



Game design

Objective

The game offers 3 modes of play: *Extinction*, *Flourish*, and *Race*. In all of these, the objective is to transform 3 tiles to Level IV.

EXTINCTION MODE

Set a timer initially for 20 mins. Players must transform 3 tiles to Level IV at the fastest Velocity in the face of extinction. When tiles advance a Level, players gain time equivalent to the Level, i.e. +2 mins for Level II, +3 mins for Level III, +4 mins for Level IV.

Table 4. Calculating velocity

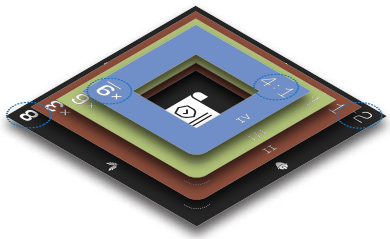
CALCULATING VELOCITY

The Velocity of a colony's transformation is calculated by the number of *Turns*÷*Duration* of the game × 40.

FLOURISH MODE

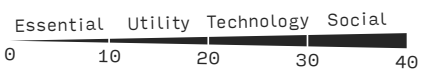
Players have unlimited time to build the ideal colony by transforming the highest value tiles to Level IV. Add the scores of the 3 highest value tiles to get the transformational Amplitude.

Table 5. Calculating amplitude



CALCULATING AMPLITUDE

A tile's value is calculated by its *Cost*÷*Return* at Level IV. For example, the Policy–Making tile's Level IV Cost is 9×8=72, and its Level IV Return is 4:2=8. Therefore, its value is 72÷8=9. The total value of a colony's Level IV tiles is the transformational Amplitude.



The Amplitude indicates the complexity of a colony's transformation, with Social transformation being the most complex.

RACE MODE

Ideal for 6 or more players in 2 to 4 teams. Teams race against each other to be the first to transform 3 tiles to Level IV. Both *Velocity* and *Amplitude* matter.

Set–up

The game consists of *Base* tiles (**1**), advancement *Levels* from II to IV (**1.1**, **1.2**, **1.3**), and Cards (**1.4**) that introduce disruptions in the form of *Uncertainties* and *Situations*. Before starting, shuffle and stack Base tiles, Levels, and Cards. Base tiles and Cards should be stacked face-down.

Starting

Start the game by placing the white *Landing* tile in the center (**2**). If playing in *Extinction* or *Flourish* modes, use ONE Landing tile. If playing in

←
Fig 8. Building a colony: Base tiles, Levels, and Cards are used during each turn to develop and transform a colony.

How-to-play Moonshot.

Watch the video »

Race mode, use TWO to FOUR connected Landing tiles, one for each team.

The turn

Each turn involves the following *5 activities*, which all players participate in simultaneously:

Table 6. Turn activities

1	Land Resources and move them to Living tiles.
2	Reveal Base tiles and Cards.
3	Invest in and connect Base tiles.
4	Resolve Uncertainties and Situations.
5	Advance the Levels of Base tiles.

1. LAND RESOURCES AND MOVE THEM TO LIVING TILES

Each turn begins with all players landing Resources returned by the Base tiles each player is invested in onto the Landing tile (**2**), and moving them to any Living tiles that are connected to the colony. The Landing tile returns +1 Resource per player per turn (**2.2**), but has a maximum capacity of 5 Resources (**2.1**). Players cannot store more than this number of Resources on the Landing tile at any given time, even if their total return of Resources exceeds this.

2. REVEAL BASE TILES AND CARDS

From the top of the stack, reveal and place face-up the number of Base tiles (**3**) equivalent to the number of players in the game.

3. INVEST IN AND CONNECT BASE TILES AND LEVELS

Each Base tile has a Cost (**3.1**) in Resources. Players can co-invest in these Base tiles by moving Resources from the Landing tile (**3.2**) or Living tiles (**4**) onto the Base tile, then connecting it to the colony on the side with a matching symbol (**3.3**).

Table 7. Co-dependent forces

4 DOMINANT AND CO-DEPENDENT FORCES

Symbols represent the influence each of the 4 dominating forces have on a Tile's function, and work as a pattern language for the colony's structure.


Scientific

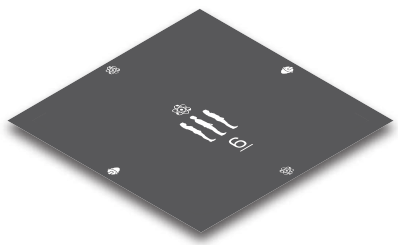

Commercial


Military


Civilian

Each Tile also increases the Return of Resources (**3.4**) per turn for all players invested in that tile. Players can invest in and connect as many tiles to the colony per turn as they have Resources for.

Table 8. Living tiles



LIVING TILES

When Living tiles (**4**) are revealed, they can be connected to the colony at no cost. They increase the colony's capacity for absorbing Resources. Players can move Resources (**4.3**) from the Landing tile onto Living tiles to convert them to specific types of Resources,

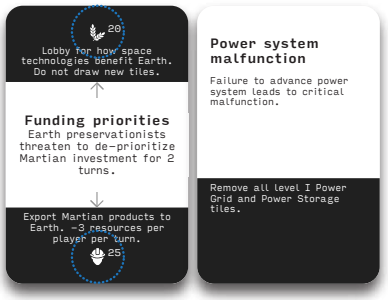
Table 8. Living tiles

represented by the symbol (**4.1**). Living tiles have a maximum capacity (**4.2**), which means players cannot store more than this number of Resources on the Living tile at any given time, even if their total return of Resources exceeds this.

4. RESOLVE UNCERTAINTIES AND SITUATIONS

Card tiles (**5**) present disruptive events to players in the form of Uncertainties and Situations. They test the players abilities to adapt and adjust to emergent strategies. Draw a Card from the top of the Card stack, and place it on the Card tile (**6**), then connect the Card tile to the colony. For Uncertainties, players must choose which of the two opposing actions and effects to invest in, then move the appropriate Resources to the action on the card (**6.1** or **6.2**). Since these are specific types of Resources (**6.3**), they can only be moved from Living tiles of the same type, and not directly from the Landing tile.

Table 9. Uncertainties and situations



UNCERTAINTIES AND SITUATIONS

Uncertainty cards present a disruption or threat with two possible opposing actions and effects. Players must align and invest in one of these actions, using specific types of Resources indicated by the symbol for each. Situation cards present a single event with one resolution.

Uncertainty and Situation cards remain in-effect and connected to the colony until they are resolved or expire.

5. ADVANCE THE LEVELS OF BASE TILES

By increasing the colony's Return through Base tiles, and its Capacity to absorb these Resources through Living tiles, as well as strategic advantages offered by Uncertainty and Situation cards, players can advance their Base tiles using Levels (**7**). In Extinction mode, each Level gains the players incremental time, but in all modes, advancing 3 Base tiles to Level IV is the goal. Players can invest in Levels any time during the turn, providing they have sufficient Resources for the Level. The Cost for each Level is a multiple of the Base tile Cost indicated by the multiplier (**7.1**), i.e. ×3, ×6, and ×9. For example, to advance Wind Power to Level III would require 5×6=30 Resources. Advancing Base tiles also increases the Return for that tile by a ratio (**7.2**). So Level III Wind Power returns 3:1 ratio of +2 Resources, meaning that in subsequent turns, players can return 6 Resources each for this tile providing the colony has the Capacity to absorb them.

Table 10. Stacking resources

STACKING RESOURCES

The space inside Level tiles is designed to fit 3×3 Resources (**7.3**), allowing them to be counted by factors of 3, 6, and 9. Using the Wind Power Base tile as an example again, the Level II Cost would be 5×3, which means stacking 5 rows of 3 Resources. The Cost for Level IV is 5×9, which means stacking 5 rows of 9 Resources.

Completing the turn

Players agree when the turn is completed after attempting all 5 activities. In most cases, this will be when players reach the limit of Resources they have available to invest in Base tiles, Levels, and resolving Uncertainties and Situations.

To complete the turn, return all unused Base tiles back to the bottom of the stack, and remove any Cards and Card tiles that have been resolved or expired.

Ending the game

The game ends when players, or the first team in Race mode to, have successfully advanced 3 Base tiles to Level IV. Calculate the colony's transformational Amplitude to discover how complex of a system players have been able to transform. If duration and number of turns have been tracked, players can also determine the Velocity at which they have been able to transform the colony.

Theoretical ideas and concepts

A significant number of theoretical ideas and concepts were drawn from material covered or collected across six disciplines: *Design*, *Systems*, *Innovation*, *Research*, *Strategy (including Game Theory)*, and *Foresight*. Many have informed or have been integrated into the design of the framework (game), while others have been used within the research process.

Expert interview

During our Second semester of our SFI program course work we had the opportunity to interview Eric Dupuis Director, Canadian Space Agency. The themes that resonated from that interview were:

1. We are a century away from viable commercial space travel to Mars.
2. Sharing and having access to data about space research is more important than necessarily owning that data.
3. Cooperation is essential to smaller space agencies, and strategically useful to larger space egencies, for achieving shared objectives.

The nature and motivational attributes of cooperation as an element of strategy became a fascinating component of the game design.

Literature

This study had us also exploring ideas and concepts from Human Factors, Foresight, Systems Thinking , and Strategy.

HUMAN FACTORS

Each player in our workshops had not played our game before, thus the rules were new to all. As players of our game, learned the rules and started to play, they took in new information (the rules) and applied them as they played. Concurrently, the game provided additional situations and uncertainties which players tried to understand and then reacted to them. Taking in new, external information, assimilate it and then apply it is known as Absorptive Capacity (Cohen, 1990). Learning new rules and being faced with additional information during game play can cause challenges to a player's Absorptive Capacity. Research in cognitive and behavioural science has suggested that having prior knowledge increases the ability to add new information into memory furthermore psychologists have advocated that such prior knowledge enhances the storage of knowledge because an individual can link information with pre-existing concepts. (Cohen, 1990). Without prior understanding of the rules and situations ones Absorptive Capacity is tested by cognitive limitations.

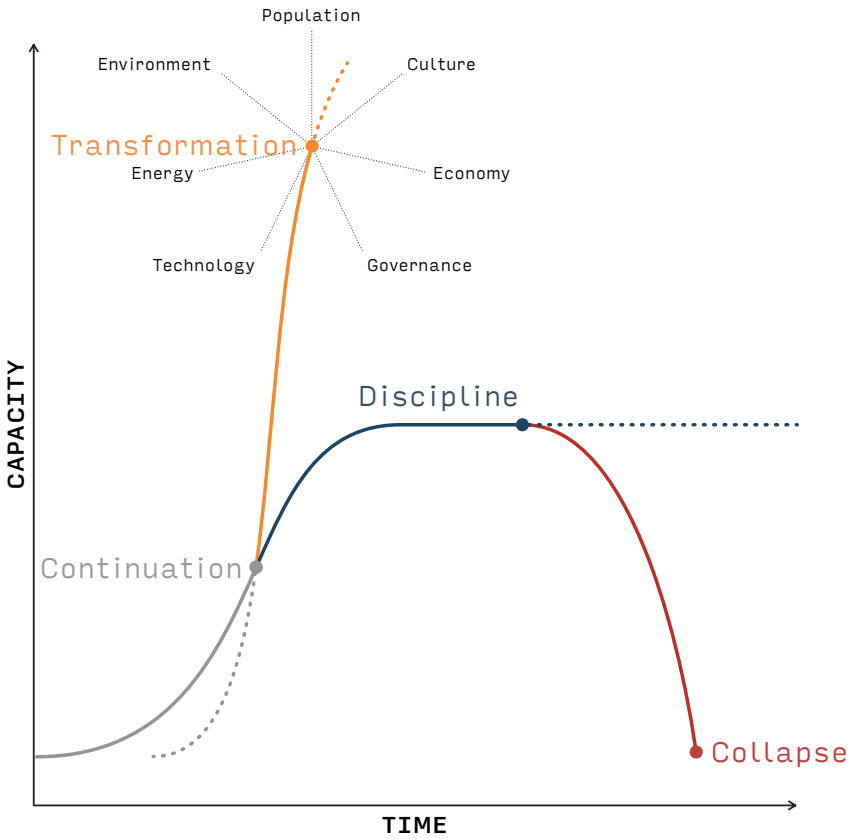
Another concept on cognitive limitations is the idea of Bounded Rationality. This idea was theorized by Herbert Simon about economic decision making which he prefers to call "satisficing" which is the combination of the words "satisfy" and "suffice". In his theory, Simon describes that the human mind is bounded by cognitive limits where when placed in situations, obtaining a satisfactory solution instead of optimal is good enough. (Economist, 2009) When Bounded Rationality is in play decisions are natural that they are not connected to any conscious deliberation (Gigerenzer, 2002). While Bounded Rationality could be considered as a players limitation, it could also be seen as a coping strategy for uncertainty. Players make decisions on where to place resources, which Action Card to invest in and how to cooperate with others, deciding on the "good enough" solution versus the most optimal putting players in a better position to win.

FORESIGHT

Strategic foresight is about understanding the possibilities in front of us to make more informed decisions today. With that being said, the future has many scenarios and it's important to consider each possible future fairly and thoroughly. We reviewed work by Jim Dator who has made it his duty as a futurist to gather and explore as many images of futures as possible Realizing that each image has its own epistemological base, logic, and their own set of facts and preferred vision that he could not definitively say that one was correct over the rest (Dator,2017). Also, understanding that no one could really consider all possible future images, he proposed that they could all be represented by four trajectories: Continuation, Discipline, Collapse, and Transformation. Futures were not bound to any single trajectory, but instead formed a narrative over all four, changing trajectories at critical inflections. This model, and the notion of perpetually changing trajectories, is foundational to our research.

SYSTEMS THINKING

The Systems Thinking Playbook (Sweeney & Meadows, 2010) introduces a wealth of simple interactive exercises that allow participants to experience fundamental Systems ideas. They are primarily aimed at group



←

Fig 9. 4 Futures (Dator, 2017):

CONTINUATION means continued or renewed economic growth—continuously replacing old with new for endless upper progression with everyone's pursuit of profit, prosperity, and progress.

TRANSFORMATION proposes that we use the knowledge we have gained and nurture it to flourish in a way where we can "lead humanity, and post-humanity, into experiences and values never before experienced on a planetary scale."

DISCIPLINE is interpreted as the discretional obedience to a higher motivation providing much more satisfaction than selfishness and capitalistic behaviours.

COLLAPSE shares the alternative outcomes of growth where failure is caused by being blinded by the false glitter of gilt, gold, and greed. (Daitor, 2017). In this future we have to acknowledge that we must learn to flourish without economic growth and understand that their are much more important things other than material possessions and consumption.

sessions, such as workshops, rather than games in the classic sense, but the metaphors and analogies utilized provided inspiration for incorporating these concepts into our game design. “Arms Crossed”, for example was a simple exercise to demonstrate that anything new can be uncomfortable since it challenges our preconceived world views. “Circles In The Air” then demonstrated how a change of perspective would allow us to see the larger picture. Furthermore, this perspective could even break from the obvious dimensionality in “Toothpick Challenge”. “Web Of Life” then illustrates wicked messes through complex multi-stakeholder relationships through a fun exercise using balls of coloured yarn, reminding us that complex problems can never be truly solved. However, understanding complex problems and finding interventions that can shift the flow of the system requires objective, unpresumptuous, observation, a mindset practiced through “Belief Release”. “Balancing Tubes” and “Dog Biscuits & See-Saws” are exercises that deal with timeframes and delays.

As Systems Thinking offers us approaches to take a macro view of problems that are epic in scope, such as those in social, political, and environmental arenas, it is suited to tackling the kinds of big world problems Jane Mcgonigal addresses in her TED Talk, Gaming Can Make A Better World (2010), and her paper, This Is Not A Game (2003). In these, Mcgonigal explores the social dynamics of collaborative and immersive play, as well as the mechanics of gaming that enable players to incrementally increase the level and challenge of their play through feedback and achievement. Systems concepts, as shown through the exercises in The Systems Thinking Playbook, can similarly be “gamified”, beginning with one element of the system and gradually expanding to the whole system. This also aligns with storytelling practices that can be borrowed, where the journey begins with the hero’s world view limited to, for example, his small village, and then grows as he ventures outwards.

STRATEGY AND GAME THEORY

A game should also provide tension, through competition and collaboration, among players, and Game Theory provides some useful theories for these. The Nash Equilibrium (Pastine et al, 2017) and Dominant Strategy Equilibrium are core concepts illustrated by games such as “The Prisoners Dilemma” and “Nuclear Build Up”. These can take multidimensional aspects, or mixed-strategy Nash Equilibrium, in games like “The Currency Speculation Game”. Or moral value and cooperation in “The Roommate Game”, which are reflected in domains including Environmental Policy.

Game Theory and Systems Thinking share similar concepts and tools, such as the use of models, cause-and-effect, iterative reasoning, and bounded rationality. When observing complex systems, we can apply Game Theory to consider the strategic outcomes of interventions on the system. Furthermore, in highly complex systems such as policy, Game Theory can help us play “infinite games” (Carse, 2011), in which goals and outcomes are perpetually changing.

Very central to our study, is a practical exploration of combining classical Game Theory with Systems Thinking in order to achieve non-zero-sum outcomes. The game is a model for applying concepts common to both theories, such as cause-and-effect, iterative reasoning, and bounded rationality. Coopetition between players yields both individual and collective pay-offs—individual players are encouraged to and rewarded for collaborating toward a common objective that has a moral cost (Pastine, et al., 2017). The multidimensional aspects of play mean that the unique strategies players can execute are too numerous to completely document. However, in designing the game, and observing players during play-testing, we can comment on several archetypes.

SIMULTANEOUS GAMES

Conventional board games, such as Monopoly, often utilize a turn-based process, in which players play sequentially (Dixit, 2008). The next player can only play the turn after the previous player has completed their turn. In reality though, players in a scenario act asynchronously and simultaneously (Pastine, et al., 2017). The dynamics of simultaneous games have been effectively demonstrated in computer real-time strategy games, introducing interesting modes of player interactions and multi-dimensional pay-offs that are less linear than turn-based games. The Nash Equilibrium, central to game theory, requires players in simultaneous games to each be mutually aware of the other active players (Dixit, 2008) when making decisions.

NASH EQUILIBRIUM

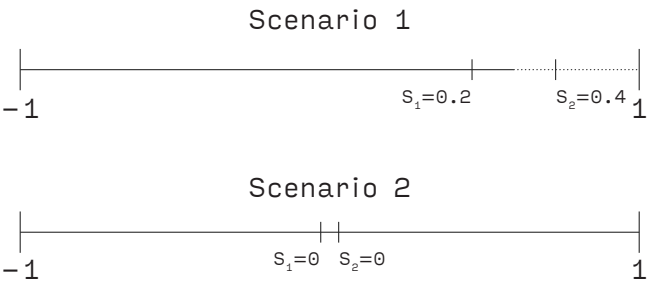
The Nash Equilibrium is a foundational concept in game theory for the counter-strategies chosen by all players to keep a zero-sum or non-cooperative game in equilibrium. In a state of equilibrium, the give-and-take effect of each player’s strategy means players neither improve nor deteriorate their situation as a result (Talwalkar, 2014). Hotelling’s Game (Hotelling, 1990) illustrates the Nash Equilibrium through a two player game. Although

involving only few rules, it shows how businesses compete for location and end up clustering together.

Table 11. Hotelling's game

HOTELLING'S GAME

Two hot dog stands are on the same stretch of a beach. Both are competing for customers over a straight shoreline. The shoreline is depicted below by a straight line where the hot dog stands can pick a location between −1 and 1. In Scenario 1, Stand 1 (S1) has the advantage since their location acquires 75% of the shorelines customers (solid line). Stand 2 (S2) on the other hand acquires only 25% of the market share (dotted line). In Scenario 2, both stands are located at the centre of the shoreline allowing both to acquire an equal amount of market share. Scenario 2 represents a Nash Equilibrium. Since both hot dog stands are located in the centre with equal market share, neither gains an advantage over their competition.



In our game the concept of the Nash Equilibrium applies when all players decide to cooperatively invest resources equally for Tiles, thereby sharing an equal pay-off in population increase.

FOCAL POINTS

Focal Points, also known as Schelling Points in honor of the economist Thomas Schelling who first described them, are defined as "a time or strategy that is natural or special in some way" (Talwalkar, 2014). These points-in-time are critical to coordination games, where multiple equilibriums exist, as they allow players to naturally coordinate in the absence of or despite communication, since players may not be able to completely discern or trust what other players say. In our game, focal points occur through Tiles, and Cards. When players coordinate to select, invest, and add Tiles to the colony, or when they coordinate to resolve challenges posed by Cards, they act on Focal Points.

MECHANISM DESIGN

The rules of our game have been intentionally designed to solicit open interaction and negotiation between players, as it is for real-life decision making. The outcomes can be collaborative, competitive, or both, depending on the nature of the players and the strategies they choose. Mechanism Design is "the study of creating rules and incentives to allocate resources in what the designers see as an efficient or fair way" (Talwalker, 2014). Players are the designers of their colony, and the soft-rules they create between them to facilitate this process, is a model of the socio-political dynamics in any new venture, such as colonizing a planet, where existing rules may not yet exist.

COOPETITION

The notion of "win-win" strategies, or coopetition, where both competition and collaboration are mutually dependent (Brandenburger & Nalebuff, 2002), suggests that non-zero-sum games can have a distinct advantage over win-lose, or zero-sum, games. A price war between two companies, in which each company continuously lowers their prices to gain market share, could trigger a disastrous negative causal loop that would put both companies out of business eventually. The Japanese have long regarded the idea of "win-win" to be a crucial philosophy of their business practices. Coopetive strategies become even more influential when infinite games (Sinek, 2016) involving wicked problems, as those at epic scales, are at stake. It lowers the barriers for resistant players and removes defensiveness by offering mutual benefit. The premise of our game, and the socio-political themes around interstellar space travel that it explores, are vast and complex, and require strategic coopetition at a multinational level.

PRISONER'S DILEMMA: COOPERATE OR DEFECT

The Prisoner's Dilemma (Talwalkar, 2014), introduces the concept of "cooperate or defect". In a multiplayer game including more than three players, the Dominant Strategy would depend on which player(s) has the strongest influence. In our play-test, all five players, including the player with the Dominant Strategy, were very cooperative. Although they were incidental "defections", all players eventually aligned with the cooperative Dominant Strategy. However, we expect in games that include more competitive players, the Dominant Strategy could defect (Dixit, 2008), either as an individual or splinter group, from the cooperative.

THE CHICKEN GAME: WHO IS MORE DOMINANT?

In the Chicken Game (Pastine, et al., 2017), competing

↑
Fig 10. Generating situations on Mars: This generative workshop was part of our Summer 2018 Independent Study project to create v1.0 of the board game.

players must predict who has the Dominant Strategy, and decide whether or not to concede to it. Since competing players do not explicitly know their opponents strategy, their decision can only be based on what is perceived (Talwalkar, 2014). This is achieved through credible shows of strength such as toughness, indomitability, fearlessness, and brinkmanship. In our playtest, the Chicken Game manifested in instances when players acted dominant through their purchasing power, i.e. their ability to afford resources for high-level tiles to rapidly increase their population, and consequently lead the direction of the colony's development.

THE ROOMMATE GAME: MUTUAL GAIN AND SHARED PAY-OFF

The Roommate Game (Pastine, et al., 2017) involves pay-offs that include a moral cost, and in which players each have mutual gain if they cooperate. This strategy is often seen in multi-stakeholder scenarios where a common impact is shared, such as environmental policy, and the current international state of space policy. If all players contribute a part, all players gain the pay-off through a

balancing causal loop (Gharajedaghi, 2011). If players play the Chicken Game instead, they risk a stand-off that perpetuates a negative causal loop. Cooperation for mutual gain and shared pay-off was a key insight from our interview with the Director of the Canadian Space Agency conducted in our earlier research, and has been intended in our game as the ideal strategy for achieving transformational victory, i.e. winning when all three Transformational tiles (ecological, social, and political) are added to the colony, and the player with the highest population leads the colony's governance.

From earlier workshops

GENERATIVE WORKSHOP

The key concept of our game was created during our independent study, which had players work together while being competitive to build a colony on mars. Essentially the game was designed to be a coopetition between players. While he had a sense of the game ,we needed help with ideas for our "Action cards" to provide situations that could occur when on the quest to colonization on Mars.

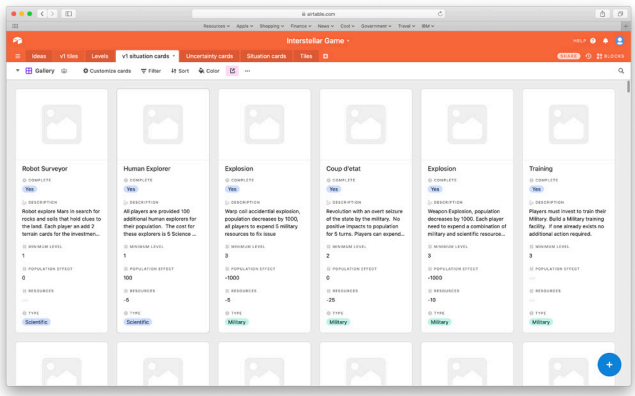
We wanted to offer upwards of 50+ various constructive and destructive situations through a deck of Cards. To accelerate the process of creating themes for these, we utilized a generative workshop with peers from our cohort. The workshop generated over 100 themes and ideas for situations that we leveraged to develop situation and uncertainty cards.

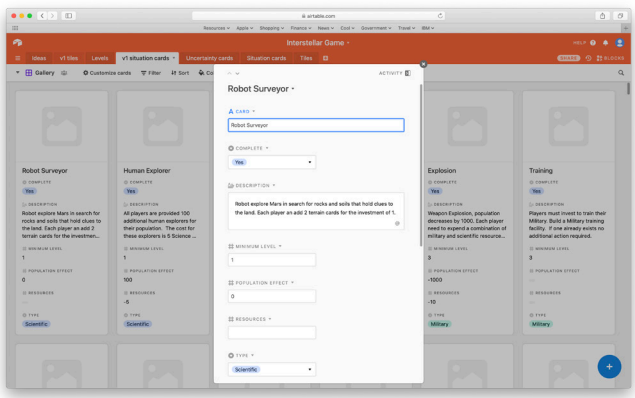
5 peers participated in a 2 hour session. We kept to a relatively simple method that was quick to prepare, fast-paced, and fun.

Our workshop toolkit included:

- Colored cue cards
- Timer
- Beads to represent resources
- Tiles to represent the current game board iteration
- Markers

We kicked-off with a short recap of our Synthesis Map, highlighting the systems concepts being designed into the game. Cooperation would be a critical strategy to winning, as mentioned above based on our expert interview with the Director of The Canadian Space Agency. Players would need to apply this strategy to construct layers of change leading to transformation, such as terraforming, social evolution, and political reformation. However, this journey would inevitably be met with





↓
Fig 11. v1 situations: Two two screenshots show the original situations generated from the workshop. They were categorized by Type (Scientific, Commercial, Military, and Civil), with fields for variables impacting game play which were further explored in our Playcentric Design approach.

→
Fig 12. v1 play test: Our first play test demonstrated that we had the basis of a viable framework for measuring organizational capacity for transformation.

disruptive challenges, which was the basis of the Cards we were going to generate through this workshop.

With the stage set, we completed four rounds of ideation with each round capturing ideas for the four primary influences or scientific, Commercial, Military and Civilian. Participants spent 10 minutes each round quickly writing constructive or destructive themes onto the cue-cards, and then 10 mins after sharing and discussing them. By the end, we generated 146 unique themes for further development into Cards.

We captured our data in AirTable (a cloud based collaboration database tool) for allowing us to view, sort, and categorize them into a structure suitable for the game.

FIRST PLAY–TEST

With our generative workshop complete and all our research and concept design done, we produced a playtestable prototype. In our final weeks of our Independent study we completed a playtest workshop to evaluate the game in practice and identify what worked and what didn't. Also we gained feedback on both rational (mechanical) and emotional (delightfulness) aspects of the game.

Fellow SFI students were recruited to playtest the first iteration of the game. Two participants had also attended our generative workshop. We participated as active observers, recording notes, feedback, and insight through the session.

Markers and note cards were provided for players to capture individual ideas and impressions. However, due to the highly interactive and collaborative experience of the game, we were able to capture all feedback together.

We completed 8 full turns in approximately 40 minutes, allowing time for discussion and optimizations to the game rules between each turn.

The playtest workshop accomplished what it was intended to do, primarily to test the theoretical mechanics of the board game, and offer further insight into the game's delightfulness, playability, and learnability. With a Design Thinking approach, we were able to quickly iterate and adapt the rules in response to the players reactions. From the playtest we gained insights on how players should collect resources during game play and how base tiles would be stacked and revealed during a turn.

Methodology

In order to define the metrics described by our Research Questions, our process and tools were selected to enable collection of the following data:

- Amount of risk players are willing to tolerate for decisions in the face of uncertainty.
- Number of turns and duration of play to complete a game.
- Types of cognitive bias, stubbornness factor, and the influence these have on player decisions and outcomes.
- Quantity and quality of decisions leading to key points of progress or decline in the game.
- Occurrences of each of the 4 future types within individual and aggregate games.

We chose to structure our approach on *Design Action Research* (Fonesca, 2013), using the board game as the framework for facilitating playcentric action (Fullerton, 2018) that was recorded and evaluated during and after the workshop. It was augmented by data from other supporting methods.

WORKSHOPS: PLAY SESSIONS OF THE BOARD GAME WITH PARTICIPANTS

Three play testing sessions were scheduled with a mix of volunteer participants ranging from 3-6 players. The board game was designed to provoke conversation during play, and therefore suitable for observational and contextual inquiry that recorded through notation, photos, and video. At the completion of each game, we invited group discussion for participants

← **Fig 13. Play testing:** During the design process, we iterated through interim play tests until we had a viable version for our Design Action Research workshops.

to share qualitative feedback and impressions of their experience, and whether the game exposed any self-discovery about their process of decision-making. Analysis of the collected data used Bardin's method of content analysis under lexical, semantic, and pragmatic units, then categorized a posteriori according to topics and elementary context units (ECU).

EXPERT INTERVIEWS: METHODOLOGICAL AND DOMAIN EXPERTISE FROM DESIGNATED ADVISORS

We selected advisors who are authorities in methodologies for systems and foresight, and domain expertise for space travel. This research was acquired through consultation, primarily in the form of conversation and electronic communication (e.g. email, messaging).

SECONDARY DATA

We drew from recorded expert interviews, playtesting, and design artifacts, conducted in prior segments of our research on the subject matter, and further augmented as necessary with additional materials from experts in related fields, including space, Games, Futures, and Systems.

LITERATURE REVIEWS

A bibliography of literature and reference media has been provided in the Bibliography section of this proposal. These have been drawn from academic, scientific, and fictional sources, and comprise of papers, books, and video material.

All collected data was codified and used to critique our primary research question, offer an ontological argument for our theories, and provide rationale for the rubric. Additionally, design insight will be integrated into a subsequent update of the board game that offers players a metric snapshot of their capacity for change as an outcome of each game.

Table 12. REB approval

APPROVED BY RESEARCH ETHICS BOARD
A proposal was submitted to and approved by the Research Ethics Board (REB) prior to the workshops permitting us to involve human participants. However, since we had no requirement for personal identification, all data collected has been made anonymous, referring only to participant number or codename.

Workshops and findings

Our workshops were structured as play-centric sessions in which participants interacted with the theoretical ideas and concepts supporting our primary inquiry through the framework (board game) we designed. 3 play sessions were scheduled on Nov 8, 12, and 15, for 1.5 hour each. Games were set for 3-6 players. Recruitment began Oct 26 using EventBrite for registration and communication, social media to promote our call-for-participants, and our project blog for information and updates about the project. All play sessions followed a common agenda:

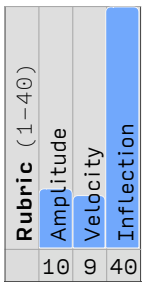
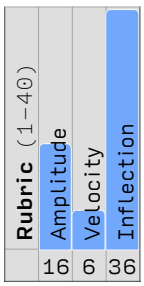
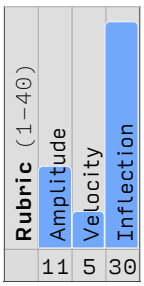
Table 13. Play session agenda

1	Welcome and assign codenames
2	Introduce them to the purpose of our study and their roles
3	Play the game with a few initial turns explaining how-to-play
4	Discuss "war stories" after the game

Refreshments were provided, and in case of distress participants were allowed to exit the session at any time without further obligation, although none did. Facilitation was kept minimal, and mainly to explain and clarify game rules, since we wanted to observe players deci-

sions and reactions to the game uninfluenced by us as much as possible. Data collection was achieved through video recording of the game board during play, and electronic data entry of turn-by-turn statistics. Results were then codified a posteriori into a matrix that used a set of formulas to derive and visualize transformation Amplitude, Velocity, and Inflection on a rubric, which could then be cross-compared between the 3 sessions.

Table 14. Play session overviews

PLAY SESSION OVERVIEWS		
SESSION #1	**SESSION #2**	**SESSION #3**
Nov 8, 2019 4:30–6:00 pm	Nov 12, 2019 4:00–5:30 pm	Nov 12, 2019 4:30–6:00 pm
4 players Extinction mode	3 players Flourish mode	7 players Race mode
		
Preview »	Preview »	Preview »

Design Action Research

Design Action Research (DAR) was originally defined as "..a research method for generating perspective design knowledge through building and evaluating ensemble IT artifacts in an organizational setting." (Sein et al. 2011). Simply put, ADR is a research method that allows researchers to gain knowledge from building and evaluating an artifact and be guided by emerging learnings from reflections. ADR is a version of Action Research which is typically used by educators as a way to improve their practice (Fonseca, 2013). It focuses on intervention and change encouraging participants to take action.

For this project we used this method to help us gain insight from our participants. The building of the colony is the artifact each game produced. The evaluation process we used to gain insight bordered Action Research because we designed interventions which were our Situation and Uncertainty cards, which changed the game and encouraged players to make decisions to move on.

Using this method allowed us to observe many different outcomes based on how players interacted with each other and the decisions the collective group made.

Recruitment

Immediately after receiving REB approval to proceed, we began our recruitment campaign on Oct 26, 2019 which ran for 2 weeks leading up to the play sessions. Session information and registration was set-up on EventBrite, where participants could register for either of 3 scheduled sessions: Nov 8, 12, and 15.

We promoted our call-for-participants through social and professional networks, primarily leveraging digital channels and word-of-mouth. The OCADU SFI #general Slack channel was a natural start as a number of our cohorts had expressed interest in participating, and some had previously participated in our earlier play test.

The EventBrite information pointed back to our project blog, where information and updates about our project were shared. We used our blog to track a journal of our progress, and as a hub for our digital media communication. Visitors to the blog could watch our Synthesis Map and How-To-Play videos, and follow the evolution of the design of the board game. EventBrite registration was also embedded on the Play page allowing participants to register directly from there.

Metrics from our EventBrite dashboard showed 224 views, with final registrations of 4 people for Nov 8, 3 people for Nov 12, and 6 people for Nov 15 (with one of these registrations for 2 people, for a total of 7 people), and giving us a response rate of 6.25% over 2 weeks.

Confirmation emails were sent to participants 3 days before their registered session explaining the session agenda, what to expect, an invitation to review the How-To-Play video on our project blog, and a request to download and complete the consent form. Following each participants play session, thank-you emails were sent with an optional invitation to complete a short anonymous online survey of their experience.

Data collection

Data collected focused on the progress of each session's game. Players were asked to refer to each other by their codenames. Video, audio, and turn-by-turn statistics were captured.

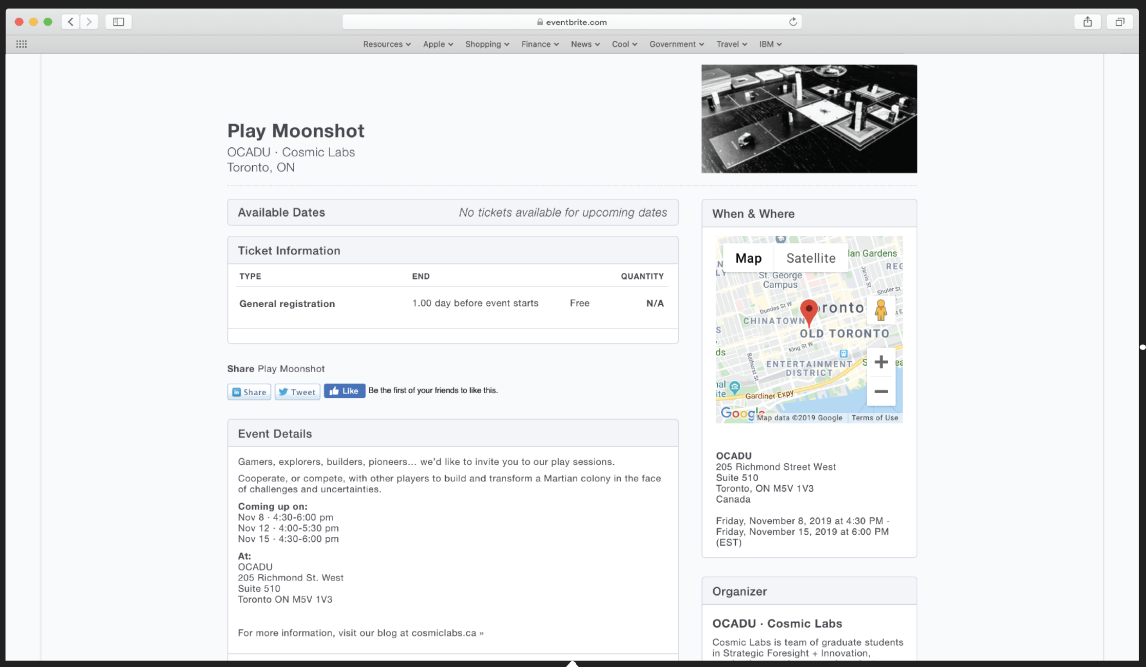


Fig 14. EventBrite registration: A call-for-participants was published using EventBrite, where participants could register for one of the 3 play sessions.

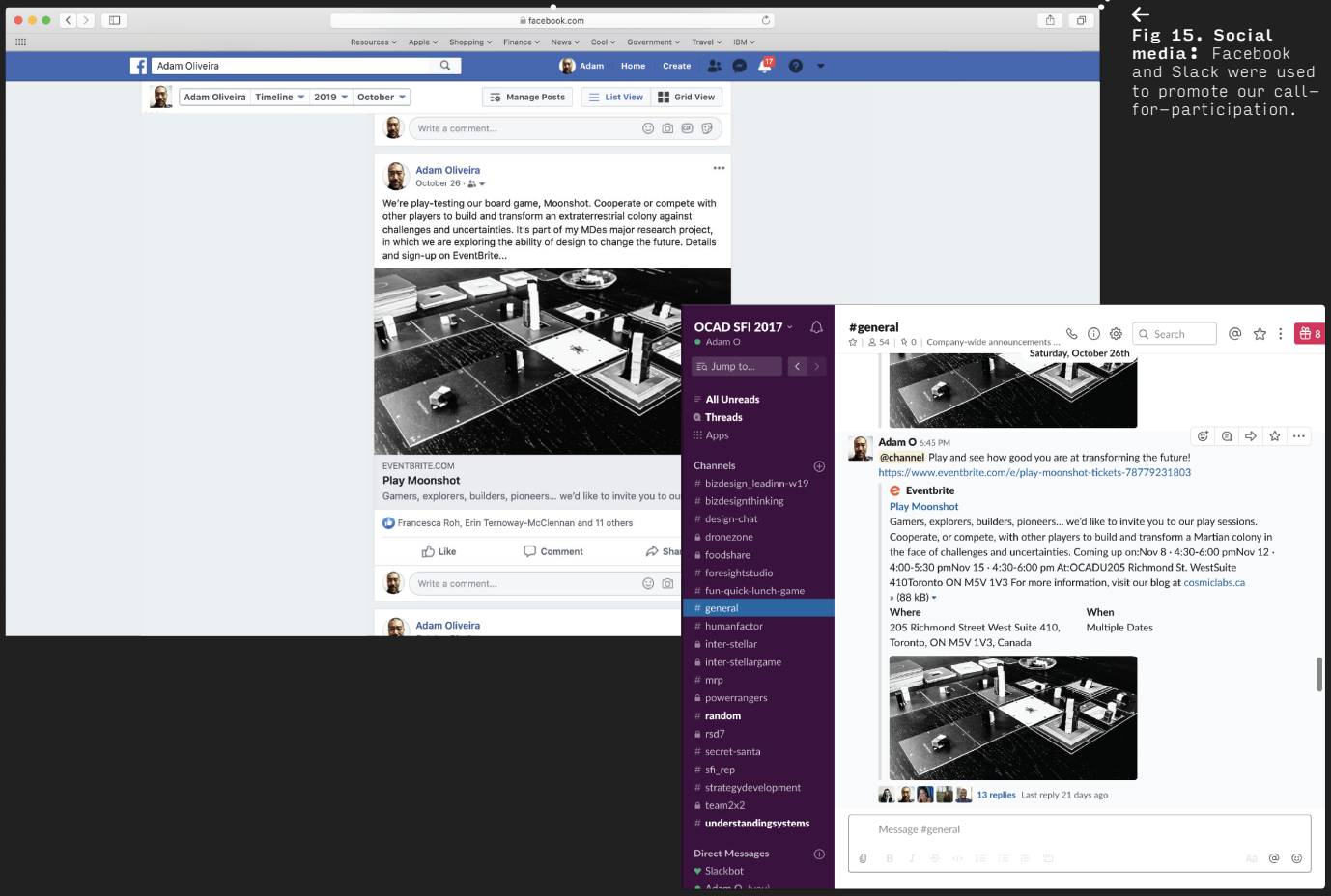
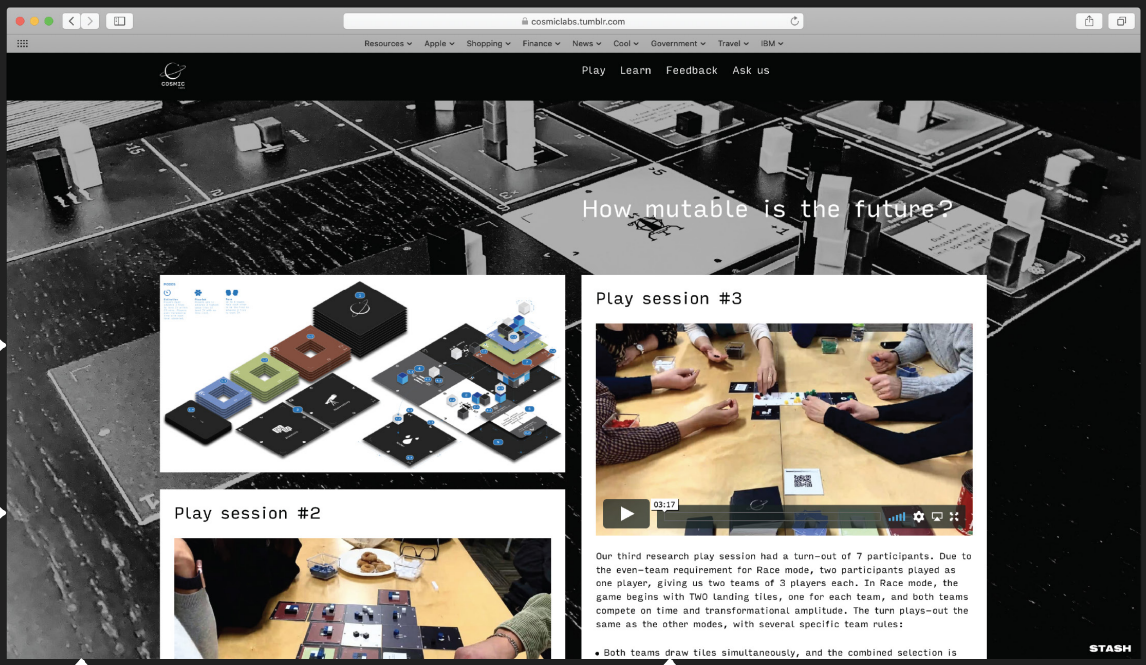
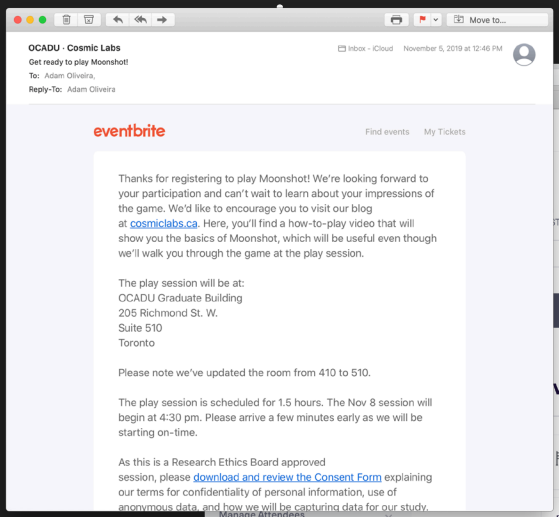


Fig 15. Social media: Facebook and Slack were used to promote our call-for-participation.

Fig 16. Project blog: EventBrite registration and social media pointed participants back to our project blog, where we posted information, images, and video about the project.





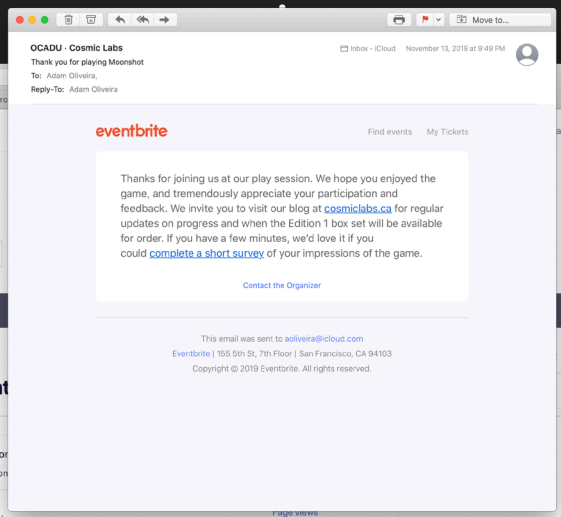


Fig 17. Communication: A reminder email was pushed from EventBrite to participants 3 days before their session date. After their session, a thank-you email was also pushed, with an invitation to complete short anonymous feedback survey.

VIDEO

We captured video using an iPhone positioned to record the game board, the activity of participants hands as they interacted with components of the game, and audio of the dialog between players. Videos were referenced during analysis to make sure statistical turn data was recorded correctly in the electronic data entry tool, and to study lexical, semantic, and pragmatic vocabulary from players dialog informing their decision-making process. The audio analysis was interpreted into high-medium-low measurements compatible with the Observations section of our data matrix.

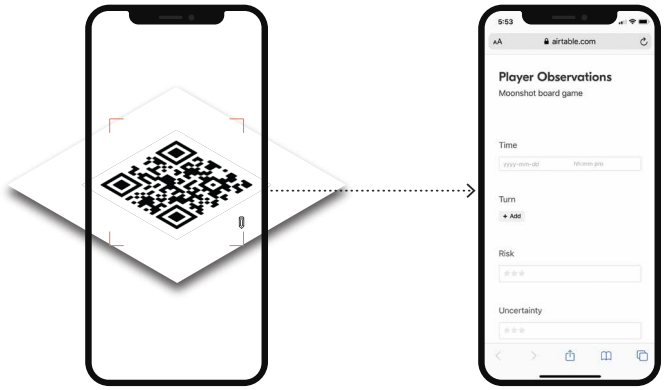
← **Fig 18. Capturing video and audio:** Video and audio of each play session was recorded on an iPhone framed to capture the activity of the game board.

TURN-BY-TURN STATISTICS

An electronic tracking tool was created with AirTable (www.airtable.com) during our preparation weeks, and accessed on an iPad during game play. The tool was a quick way for us to capture turn-by-turn statistics by tapping and selecting elements of the game. The tool presented some glitches in the first play session, limiting what we could efficiently capture, which we fixed for the second and third play sessions. This is an example of how live-testing will often surface usability bugs. Fortunately, all data was audited against the videos during analysis, and corrected for errors.

Each game was set-up in the data-entry tool with players by their codenames. For each turn, it captured what new Base tiles were added and advanced, and which players were invested in each tile. The tool then calculated the total number of Resources returned to each player per turn from tiles, capacity of the colony, and how many could be absorbed by the colony.

We had also prepared a tile with a QR code that pointed players to an online form they could access by smartphone, however players felt this was too distracting from the game play and skipped using it.



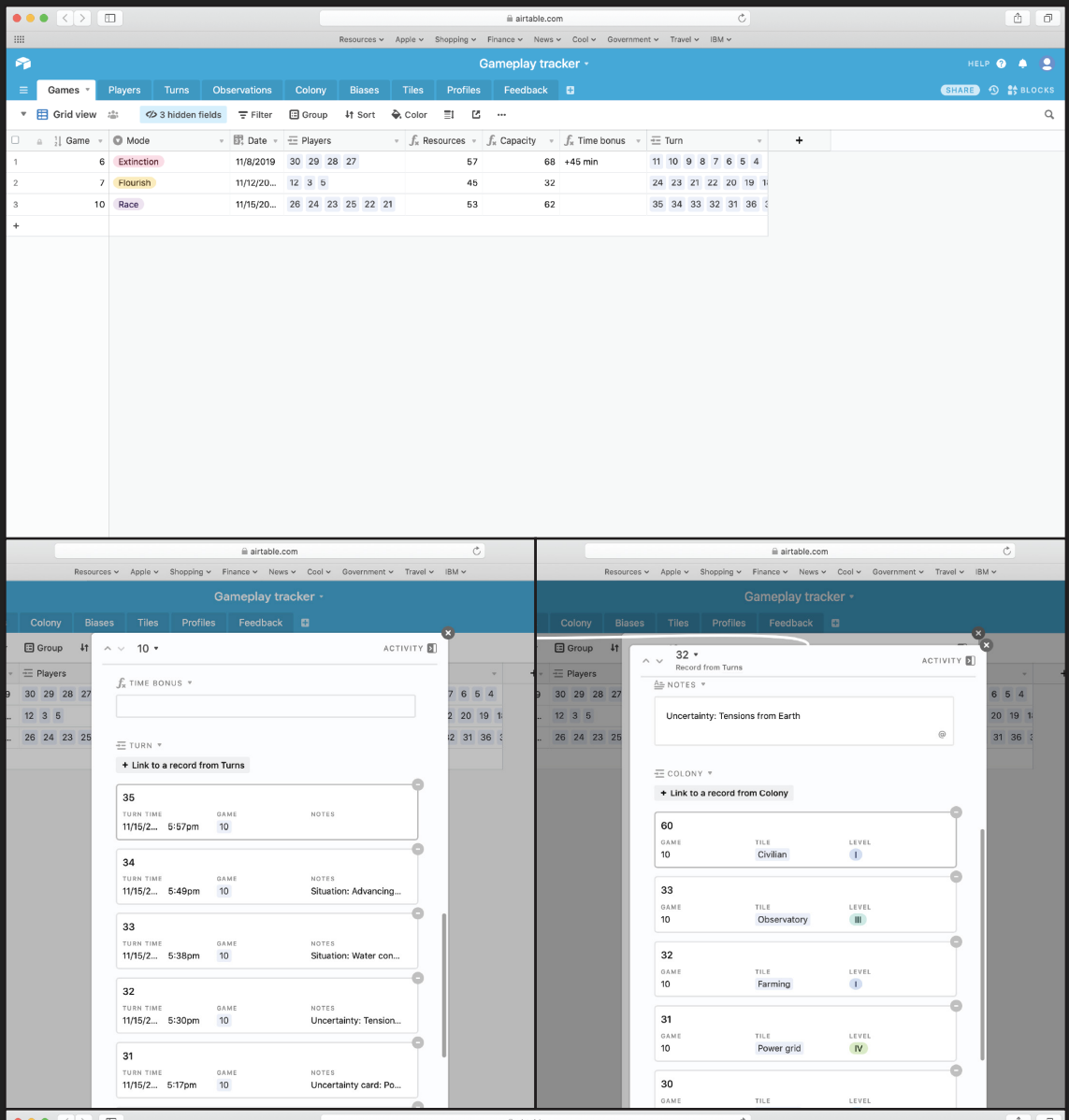
Since game statistics were tracked live, players scores were readily available at the end of each game.

Analysis and insights

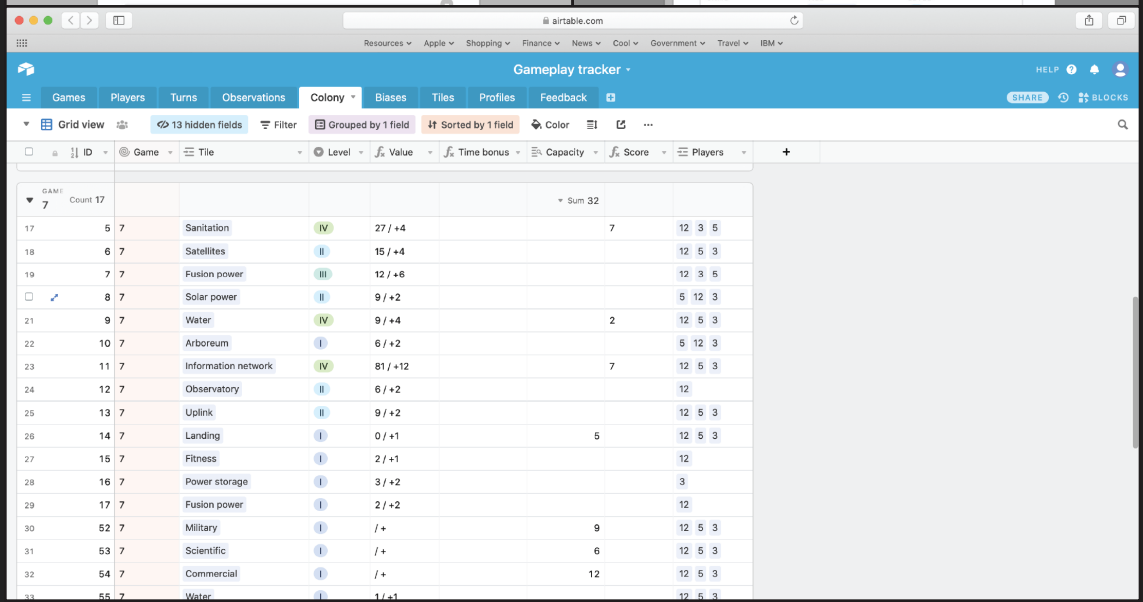
As the intended outcome of our inquiry was to establish a base rubric for dimensionality and patterns suggestive of dynamic future trajectories, the framework had been optimized for capturing quantitative data. Analysis was informed mainly by turn statistics, with observational data represented by high(9)-med(3)-low(1) numerical notation. Data from each play session was codified into a matrix, and audited against the videos for accuracy. Duration, capacity, resources, and tiles were noted for each turn, while observations for threats, risk, uncertainty, and decision influences were noted whenever the game was affected by Situations or Uncertainties. Amplitude and Velocity were calculated by the matrix according to formulas described in the Framework section. However, to calculate Inflection, we used formulas that identified trends in the advancement of tiles—tiles that remained at Level I pointed to Collapse, tiles at Level II showed Continuation, tiles at Level III were Discipline, and tiles advanced to Level IV were considered Transformational. This categorization allowed us to track the different trajectories of multiple dimensions of the colony rather than a single generalized trajectory. We see then, in the visualizations of each session's Future Outlook, that the waveforms are polyrhythmic, showing asynchronous but simultaneous movements of all 4 future trajectories. The frequency of the inflections between these 4 futures were calculated as a metric alongside Amplitude and Velocity. All 3 scores were standardized to a scale of 40.

→
Fig 20. Tracking tool: Electronic game tracking tool created in AirTable for tracking and calculating turn-by-turn data.

←
Fig 19. Mobile tracking form: Players could link to a mobile form by scanning a QR code tile, where they could submit turn-by-turn observations.



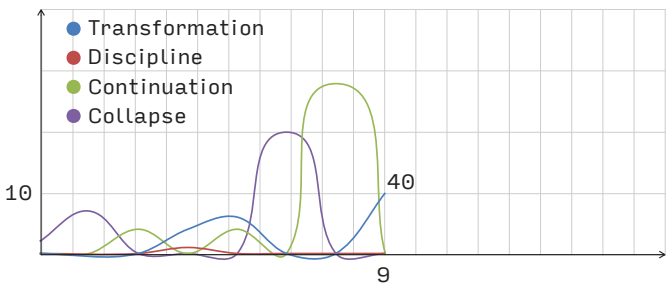
→
Fig 21. Transformational score: The tranformational score of the players colony was calculated from turn-by-turn game data.



PLAY SESSION #1
Nov 8, 2019 · 4:30–6:00 pm

Extinction	8	25m	Water	Power Grid	Fusion Power	1

First of 3 official research play sessions. We had 4 players, 2 of who were experienced board-gamers. We did not require specific age or gender in the selection, but general age range of this group was adults between 25-50 years. Extinction mode was set for initial 30 mins, with time gained during play. A total of 8 turns were played. Players transformed Water, Fusion Power, and Power Grid tiles to level IV by turn 5, with approximately 20 mins remaining on the timer after factoring gained time. A further 3 turns were played after this, yielding transformation of the Farming tile to level IV. Although transformation Velocity was high, their total transformation Amplitude for the first 3 Level IV tiles ranked 6 on a scale of 40, placing them at the Essential range. Investment of resources favored efficiency and speed rather than optimization. On posterior discussion, this approach was motivated by an uncertainty of what could be accomplished within the time-limit. Realizing interim advancements gained them time, decisions to invest in higher order tiles or a strategy of incrementally increasing quality of investment might have been preferred. This suggests that initial perceptions of fixed time-limits can predispose groups to prioritizing "low-hanging fruit" that can be gained quicker than " long-game investments" where gains are less clear but potentially more socially transformational. Progress of the colony was disrupted by only 1 Uncertainty card, that was considered a "low risk" uncertainty by the players. Their path to transformation was therefore very stable and predictable, showing steady decline of Collapse, transition into Continuation, and onto Transformation, with no requirement for Discipline. Inflection was high between these trajectories because of the high Velocity. More occurrences of Situations and Uncertainties would likely have challenged this.



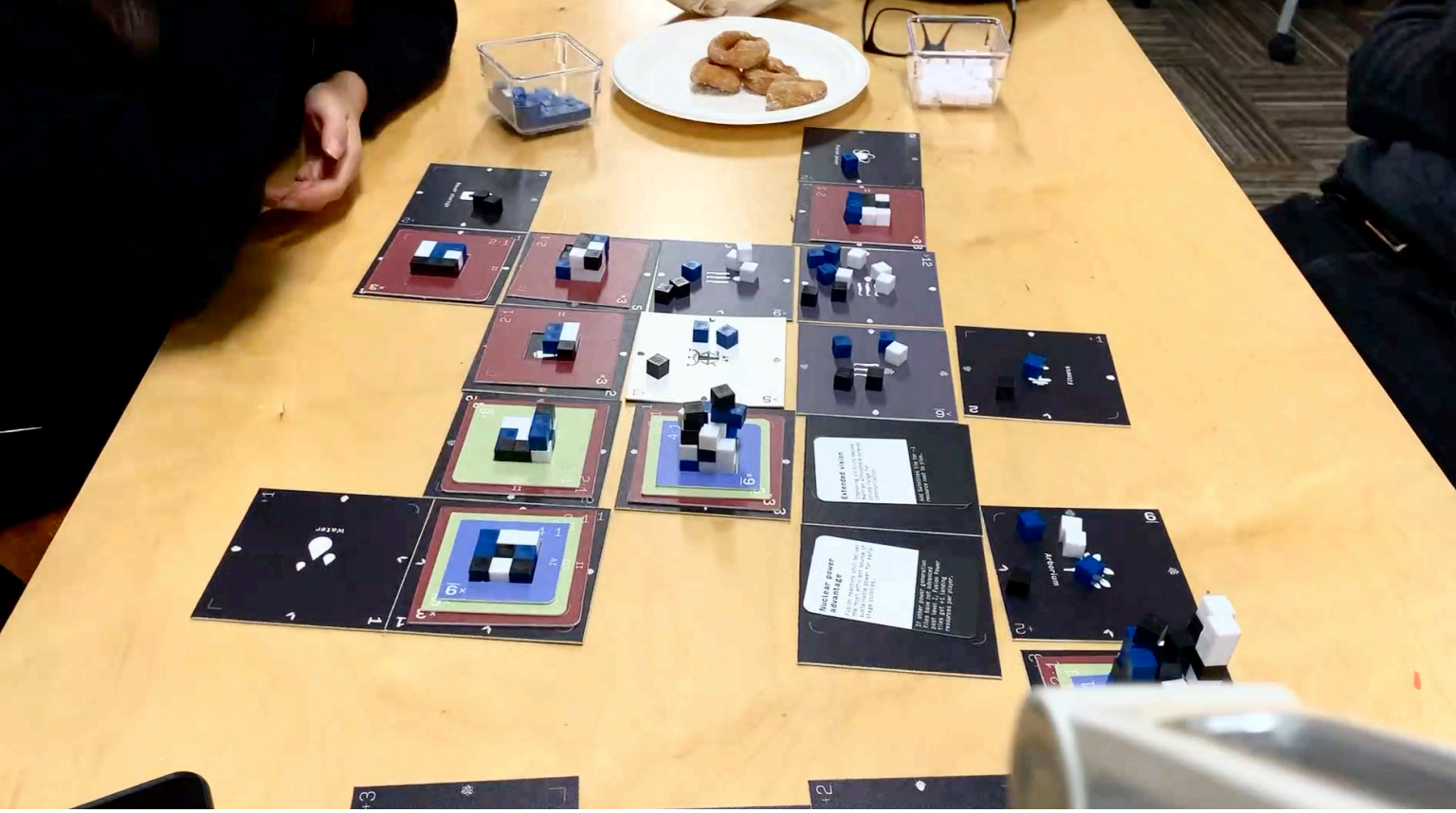
←
Fig 22. End of session #1: State of the game board by the end of the first play session.

#1. Extinction mode

→
Table 15. Session #1 codified data: Turn-by-turn data from play session #1 codified into a matrix that calculates transformational amplitude, velocity, and inflection.

Measurements	Unit			Rubric (1-40)	Amplitude	Velocity	Inflection	Turns 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
					10	9	40							» Extended play														
Duration	Mins					36		0	2	2	2	14	5	7	3	1												
Time bonus	Mins										4	19	6	2		9												
Capacity	<								5	14	29	29	29	29	44	44												
Resources	+ (absorbed)																											
Mr. Fantastic									1	3	8	11	5	4	9	14												
Thor									1	3	6	6	9	7	12	7												
Spider-Man									1	3	8	6	5	4	7	4												
Iron-Man									1	3	6	6	8	7	14	12												
Colony	Cost	Resources	Capacity																									
Landing		+1	<5					·																				
Waste renewal	4	+2							I					II														
Military			<9						·																			
Medical	8	+3								I			II															
Fusion power	2	+2			2					I	II	II	IV															
Water	1	+1			2					I	II	IV																
Civilian			<15							·																		
Power grid	2	+3			2						I	IV																
Expeditionary	7	+1												I	II													
Currency	8	+3												I														
Farming	5	+3			4									I		IV												
Civilian			<15											·														
Policy-making	8	+2													II													
Governance	6	+1													I													
Commercial			<12													·												
Commercial			<12													·												
OBSERVATIONS																												
Threats	(number of cards)						1				1																	
Risk	L=1, M=3, H=9						1				1																	
Uncertainty	L=1, M=3, H=9						1				1																	
Bias type																												
Stubbornness	L=1, M=3, H=9																											
Key decisions	Qty																											
Decision influence	L=1, M=3, H=9																											
Scientific							0				1																	
Commercial							3				3																	
Military							1				1																	
Civilian							9				9																	
Future outlook	L=1, M=3, H=9																											
Transformation	IV						3		1	1	1	9	9	1	1	9												
Discipline	III						0		1	1	1	3	1	1	1	1												
Continuation	II						2		1	1	9	1	3	1	9	1												
Collapse	I						3		9	9	1	1	1	9	1	1												

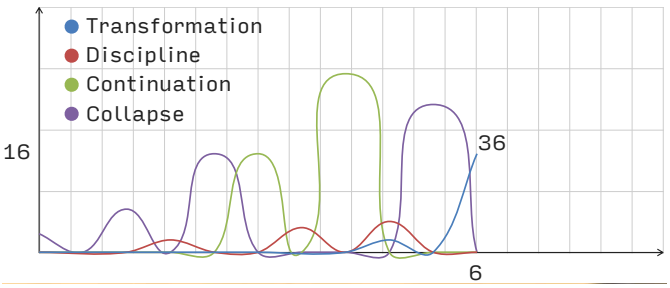
←
Fig 23. Session #1 future trajectories: Data from the matrix visualized into 4 simultaneous and polyrhythmic future trajectories.



PLAY SESSION #2
Nov 12, 2019 · 4:00–5:30 pm

Flourish	11	72m	Water	Sanitation	Information Network	5

In our second research play session, we set the game to Flourish mode with 3 players. In this mode, there was no time limit, other than what was available within the scheduled 1.5 hour session. Flourish mode is intended to remove perceived temporal constraints and open the game for players to transform tiles that score the highest Amplitude (30-40). Velocity was slower than the play session #1, as the number of turns (12) and average time per turn (6 min) increased through more fully evaluated discussions and decision-making, even though there were fewer players. Tedious activities such as calculating and allocating resources were carried out with less negativity, and even enjoyably by some players. In response to feedback from the previous play session, we increased the occurrences of Situation and Uncertainty cards. Players noted that Situations and Uncertainties caused, to a larger or smaller degree, disruptions to their resources and consequently strategies, and required them to respond and/or pivot as needed. Despite intentions to reach a transformational Amplitude of 30-40, Situations and Uncertainties reduced their capacity to achieve this. The team eventually transformed Water, Sanitation, and Information Network tiles for a total Amplitude of 16, placing this colony at the upper scale of the Utility range. This shows a marked elevation from the low Amplitude of the colony in Extinction mode, even with significantly increased Situations and Uncertainties. Interestingly, we note periods of Discipline occurring early in the game, suggesting a “slow-and-steady” conservative approach, transitioning later into Continuation and eventually Transformation. A new Collapse trajectory begins to appear in the later turns as players began to return to expanding Base tiles after 3 Level IV advancements were achieved, signaling the start of a new Inflection cycle.



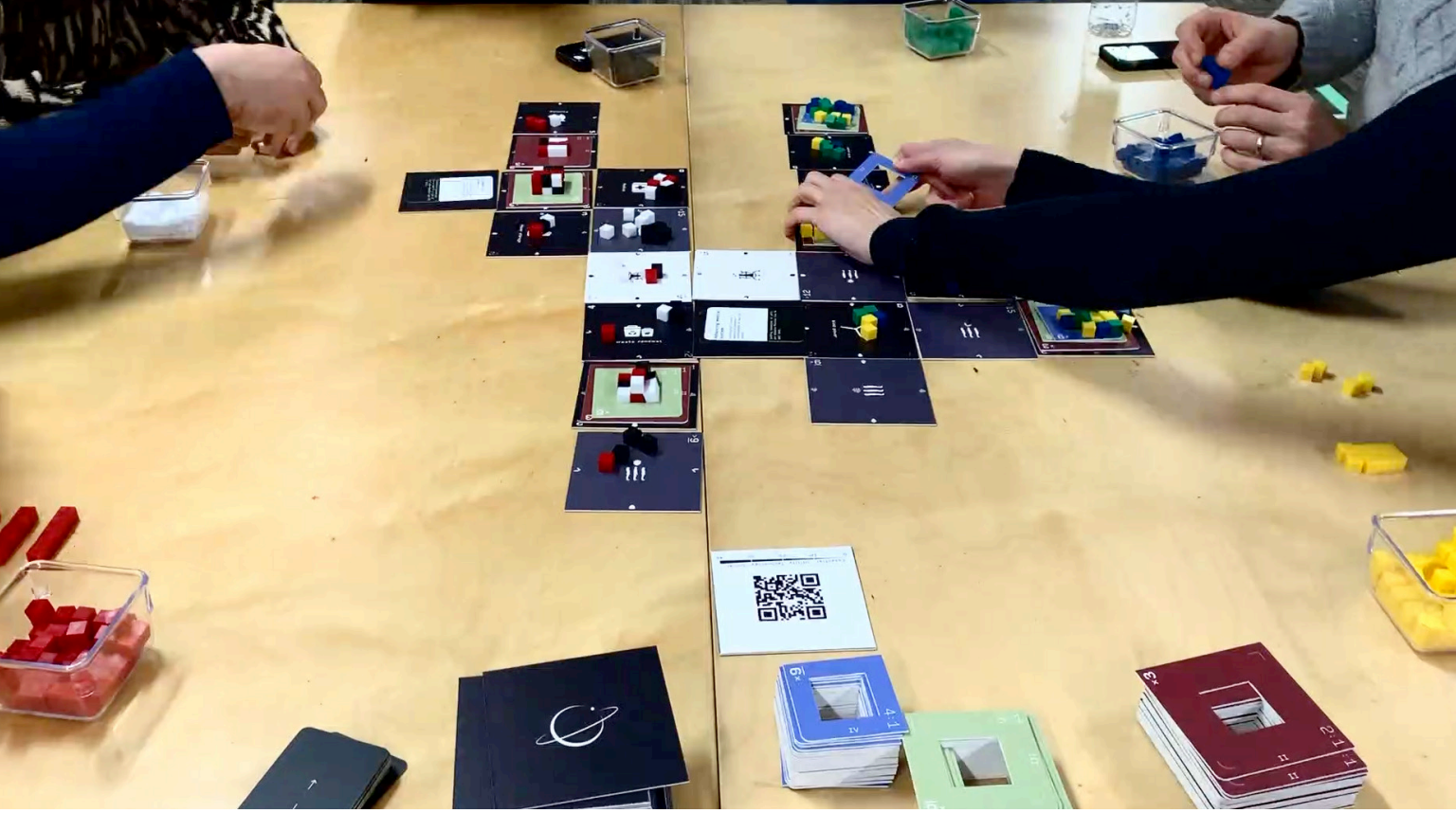
←
Fig 24. End of session #2: State of the game board by the end of the second play session.

#2. Flourish mode

→
Table 16. Session #2 codified data: Turn-by-turn data from play session #2 codified into a matrix that calculates transformational amplitude, velocity, and inflection.

Measurements	Unit			Rubric (1-40)	Amplitude	Velocity	Inflection	Turns 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
					16	6	36																					
Duration	Mins					72		0	6	7	5	10	7	12	5	7	6	5	2									
Time bonus	Mins																											
Capacity	<								5	5	14	20	20	20	20	32	32	32	32									
Resources	+ (absorbed)																											
She-Hulk									1	2	2	4	4	7	5	11	8	11	11									
Captain Marvel									1	2	2	4	5	4	5	11	10	11	9									
Silver Surfer									1	1	2	6	3	4	7	9	11	10	11									
Colony	Cost	Resources	Capacity																									
Landing		+1	<5					·																				
Sanitation	3	+1			7				I			II						III	IV									
Military			<9							·																		
Scientific			<6								·																	
Satellites	5	+2									I			II														
Fusion power	2	+2									I		II		III													
Solar power	3	+1										I		II														
Water	1	+1			2							III					IV											
Arboreum	6	+2											I															
Information network	9	+3			7								I			II	III	IV										
Observatory	2	+1												I		II												
Commercial			<12												·													
Uplink	3	+1													II													
Fitness	2	+1														I												
Power storage	3	+2															I											
Fusion power	2	+2																I										
Water	1	+1																I										
OBSERVATIONS																												
Threats	(number of cards)						5			1		1	1	1		1												
Risk	L=1, M=3, H=9						1			1		1	1	3		1												
Uncertainty	L=1, M=3, H=9						1			1		1	1	3		1												
Bias type																												
Stubbornness	L=1, M=3, H=9																											
Key decisions	Qty																											
Decision influence	L=1, M=3, H=9																											
Scientific							2			9		9	1	1		1												
Commercial							2			3		9	9	3		1												
Military							1			3		1	1	9		1												
Civilian							0			1		1	3	1		1												
Future outlook	L=1, M=3, H=9																											
Transformation	IV						2		1	1	1	1	1	1	1	1	9	1	9									
Discipline	III						2		1	1	1	9	1	1	9	1	3	1	1									
Continuation	II						2		1	1	1	1	9	1	9	1	1	1	1									
Collapse	I						4		9	1	9	1	9	1	1	1	9	1	1									

←
Figure 25. Session #2 future trajectories: Data from the matrix visualized into 4 simultaneous and polyrhythmic future trajectories.



PLAY SESSION #3
Nov 15, 2019 · 4:30–6:00 pm

Our third research play session had a turn-out of 7 participants. Due to the even-team requirement for Race mode, two participants played as one player, giving us two teams of 3 players each. In Race mode, the game begins with TWO landing tiles, one for each team, and both teams compete on transformational Amplitude and Velocity. The turn plays-out the same as the other modes, with several specific team rules:

Both teams draw tiles simultaneously, and the combined selection is available to both teams. First-mover advantage and trade bargaining for tiles are activities players can engage in.
Situation and Uncertainty cards apply to both teams, but their affects are specific to each team. Teams can also invest in different options on Uncertainties, consequently yielding different outcomes in their strategies. If both teams achieve transformation on 3 tiles simultaneously, the team with the higher Amplitude wins.

Although both teams expanded fairly evenly for the first half of the game, Team A accrued 3 Living tiles by midway, giving them a large absorptive capacity to import resources. They were therefore able to pursue an aggressive Inflection at this stage from Collapse to Transformation that springboarded them ahead of Team B. However, one of their players advocacy for sustainable choices (and potentially higher transformational Amplitude) was overruled by their de facto team lead's economically pragmatic preferences. While this accelerated their transformation Velocity in exchange for a lower transformation Amplitude, their higher Velocity may not have been necessary to win if more attention had been paid to Team B's strategic disadvantages.

This is because Team B's primary obstacle was only having one Living tile that severely limited their absorptive capacity. Although each player had a high return of resources from tiles, the capacity of their colony for absorbing them meant most of those resources could not be utilized. Their trajectory was analogous to marginalized populations, unable to mobilize competencies due to lack of capacity, and constrained to cap their Continuation at a certain threshold with Discipline. Although Team B managed to build an ample base of tiles, they were challenged to advance their tiles beyond level III.

←

Fig 26. End of session #3: State of the game board by the end of the third play session.

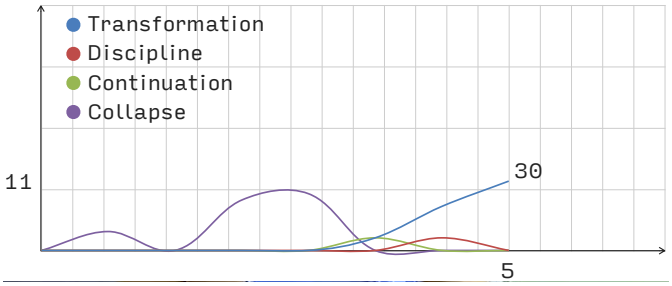
#3. Race mode

→

Table 17. Session #3 codified data: Turn-by-turn data from play session #3 codified into a matrix that calculates transformational amplitude, velocity, and inflection.

				Rubric (1–40)	Amplitude	Velocity	Inflection	Turns																										
Measurements	**Unit**				11	5	30	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Duration	Mins					62		0	6	14	7	6	8	11	8	2												
Time bonus	Mins																											
Capacity	<								5	17	17	17	17	32	32	38												
Resources	+ (absorbed)																											
She-Hulk									1	1	3	3	4	8	8	12												
Captain Marvel									1	1	3	2	3	8	8	13												
Ant-Man									1	1	3	1	1	9	9	13												
Colony	Cost	Resources	Capacity																									
Landing		+1	<5					·																				
Commercial			<12						·																			
Enforcement	5	+2								I																		
Wind power	5	+2										I																
Food storage	5	+3			4							I		IIIII	IV													
Civilian			<15										·															
Power grid	2	+3			2								I	IV														
Wind power	5	+2												I														
Scientific			<6												·													
Fitness	2	+1			5										IV													
Capacity	<								5	20	20	20	20	20	20	29												
Resources	+ (absorbed)																											
The Wasp									1	1	3	3	4	4	6	7												
Scarlet Witch									1	1	3	3	5	4	6	9												
Dr. Strange									1	1	3	3	5	3	6	9												
Colony	Cost	Resources	Capacity																									
Landing		+1	<5					·																				
Civilian			<15						·																			
Waste renewal	4	+2								I																		
Uplink	3	+1										I		IIIII														
Medical	8	+3										I																
Sanitation	3	+1											I	II														
Farming	5	+3											I															
Observatory	2	+1											I	IIIII														
Power storage	3	+2												I														
Military			<9																									
OBSERVATIONS																												
Threats	(number of cards)						6				1	1	1	1	2													
Risk	L=1, M=3, H=9						9				3	9	9	1	1													
Uncertainty	L=1, M=3, H=9						3				3	3	9	1	1													
Bias type																												
Stubbornness	L=1, M=3, H=9																											
Key decisions	Qty																											
Decision influence	L=1, M=3, H=9																											
Scientific							1				9	1	1	1	1													
Commercial							0				1	1	1	1	1													
Military							0				3	3	3	1	1													
Civilian							2				1	9	9	1	1													
Future outlook	L=1, M=3, H=9																											
Transformation	IV						3		1	1	1	1	1	9	9	9												
Discipline	III						0		1	1	1	1	1	1	3	1												
Continuation	II						0		1	1	1	1	1	3	1	1												
Collapse	I						3		1	9	1	9	9	1	1	1												
Future outlook	L=1, M=3, H=9																											
Transformation	IV						0		1	1	1	1	1	1	1	1												
Discipline	III						1		1	1	1	1	1	1	3	1												
Continuation	II						1		1	1	1	1	1	3	1	1												
Collapse	I						3		1	9	1	9	9	1	1	1												

8 turns were played, with an average duration of 9 mins per turn. Overall Velocity may have been slowed by the larger group of players and increased complexities from the additional game rules for two competing teams. Team A's colony achieved an amplitude of 11 from Food Storage, Power Grid, and Fitness tiles, placing it at the low range of the Utility scale. Had the game progressed for a longer time, and their strategy adjusted for their absorptive capacity advantage over Team B, a higher Amplitude with Technological or Socially transformational tiles might have been achieved.



←
Fig 27. Session #3 future trajectories: Data from the matrix visualized into 4 simultaneous and polyrhythmic future trajectories.

SEMANTIC ANALYSIS

Recorded audio was transcribed into text, and a semantic analysis was conducted for themes and words that informed players decision-making process. They were then organized into a lexicon by sessions, words, and frequency.

Numbers came up frequently as players were counting the resources they were accumulating and expending during each turn. That being said, the number two was the most frequent number in each session mainly due to us explaining the different modes of games and game play. Additionally, in sessions #2 and #3, players revealed cards that had them divide either their resources by two or halving the capacity of their living tiles.

The Sanitation card was not revealed in play session #1, however *Sanitation* frequently came up in sessions #2 and #3 as players realized there was a benefit to the return of that card when it was revealed. This also helped with transformational amplitude at the end of the game.

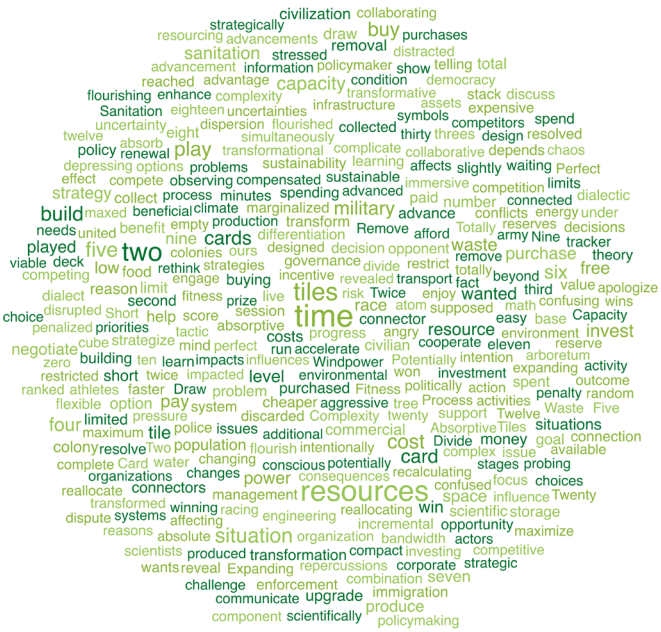
Resource allocation is important as players try to build their colony in each game type. With that being said, it is not surprising that *Resources* was on of the most frequent words in our review.

Time was another frequent word identified in all three sessions. The lexical search completed for this word showed that in context the word wasn't being used frequently as part of game play with the exception of session #1. Time was important during that session as there was a time limit and as you advance in the game you gain time. Players were excited about gaining time and this was a deciding factor as they advanced their tiles.

Power and water cards (*Fusion*, *Water*, *Solar*) were common essentials in each game, requiring relatively low investment, so these appear with some degree of frequency. In play sessions #2 and #3 cards were revealed that placed players in situations were their resources were impacted positively or negatively based on the power generation tiles added to the colony.

Session #1		Session #2		Session #3		Combined	
WORD	FREQUENCY	WORD	FREQUENCY	WORD	FREQUENCY	WORD	FREQUENCY
two	30	resources	52	time	71	resources	137
six	24	two	50	resources	63	two	130
resources	22	power	47	need	50	time	114
nine	20	time	32	two	50	tiles	89
spend	20	level	31	living	47	six	78
tiles	16	six	31	tiles	46	power	67
eight	13	five	28	game	39	five	66
generate	13	nine	28	five	29	nine	59
upgrade	13	tile	27	situation	28	level	53
four	11	tiles	27	cost	27	play	53
minutes	11	play	23	times	27	situation	52
time	11	situation	20	build	26	tile	48
five	9	invest	15	play	26	cost	45
generating	8	twenty	15	buy	24	four	45
level	8	seven	14	card	23	buy	42
water	8	buy	13	six	23	invest	38
afford	7	four	13	cards	22	build	34
decision	7	cost	12	military	22	card	33
power	7	number	12	capacity	21	capacity	32
twenty	7	colony	11	four	21	military	32
cost	6	sanitation	11	invest	18	upgrade	32
thirty	6	upgrade	11	matter	18	cards	30
buy	5	fusion	10	move	18	sanitation	27
card	5	wanted	10	pay	17	spend	27
fusion	5	free	9	sanitation	16	wanted	27
invest	5	goal	9	tile	16	free	26

↑
Table 18. Semantic lexicon: Semantic analysis of words transcribed from recorded audio organized by sessions, words, and frequency.



↖ **Fig 28. Session #1 wordcloud:** Themes of time constraints (two minutes) and maximizing resources for efficiency.

↑ **Fig 29. Session #2 wordcloud:** Themes that show conscious effort to advance the human condition.

← **Fig 30. Session #3 wordcloud:** Themes showing more aggressive characteristics from competition.

→ **Fig 31. Combined wordcloud:** Common to all, themes around the stocks–and–flows of resources were fundamental to development.


Sanitation performing strategically
organizations
maximization operating
generate
depends cheaper episode environmental winning
divide advancements collaborating allocate demoratic
immersive doctor collaborator investment
progress
sanitation communicate situation collaboration
competition
depressing uncertainty engineering construction absolute dispersion absorb
expense
cards Perfect production money combination collect calculation six eighteen
arboretum economic build twelve intentionally Twenty affecting
upgrades Uptake card Capacity accelerate upgrade designed slightly maximize
spend Remove strategies
fighting flexible situations society climate discuss stock democracy Complexity
cleared inside twice patient . incentive
incremental operate math nine transformative removal influences rounds connectors impacted
chaos ten complicate organization Fusion opportunity enforcement process modify sustainability scored
negotiate Build growth Twelve problems generation theory conscious fact flourishing Ballistics
survival investments situational Aesthetically corruption test Number renewal
Seven tree competing absorptive population third minimal racing smart here ninety
influence overall fifteen connection changing contain reveal producing risk tradeoff reaction Civilians
advance army Four Refresh purchases confused flourished potentially groups Patrice stack enjoy
colonies beyond dust pileup flourish owe number uplink destruction choice Dialect under stressed
photos forty poetry play reason oven apologize investing effect trade mind united assortment fourth
ambition positive Windpower threes generating help counted Two activities cost draw issue
intention subtract balance Potentially discard
open Seventeen assets problem scientific military totally generated paradigm occasion civilian atom
telling complex advanced revealed disrupted Draw goal perceived available costs
resolve invest four Water Five own win food complexity zero value cube waste adding running nuclear
fitness eleven fusion overnights addition live resources compete hope export learn faster
Nine Time gap wants options sixteen limits pieces marginalized picking missed
Nineteen support Sixteen downside spent Twice fifty policy easy payoff maxed colony low police choices level empty
eight calculate Ninety Trade changes Expanding benefit dialectic Level score realize strategy nurses
penalized reached tracker session agreed ours race confusion decisions opposite option purchase division engage waiting activity
water total design ratio lowest free Army issues conflicts existence twenty expanded period sources learning pivoted
deliver condition Six peer goodness Waste seven resource philosophy tile valid energy penalty spending
pilot Process Card mission peace complete strategize overload athletes needs networks perfect Fitness
deck space Stack pay afford picked information viable confusing overcrowded enhance reasons short
grow Short time palming five component power observing action second reserves ping
affect farming two show storm bandwidth cut capacity missing paid strategic resolved
Thirty Tiles buying buy Divide transformational Decisions encircling fourteen plenty base conspire
limited system Nuclear eighty Ransley technologies advantageous sustainable produced recalculating nineteen won compact
outcome losing abundance connector emotions phone cooperate supposed pointing
abacus minutes Race collected immigration aggressive investor angry building
contemplate limit Absorptive run maximizing beneficial actors
dispute maximum diversify competitors war policymaking capacitors expanding
systems collaborative advantage overseas Expensive consequences governance grows
party Eighteen Storage transform discarded purchased dialect focus symbols
requires distracted connected impacts produce tiles wanted
thirty challenge transformation SITUATION perfectly environment
representation simultaneously compensated civilization opponent
decision advancement competitive storage corporate affects Totally
Resources differentiation continually infrastructure additional
management fairness pressure uncertainties
mathematically commercial
missiles

Discussion

←
Fig 32. One small step for a man, one giant leap for mankind (Armstrong, 1969): Astronaut's foot on the Lunar surface from the Saturn–Apollo 11 mission. Image made available to public domain by NASA.

In the 1950-60s, the world momentarily looked away from our inordinate social upheavals, and instead at the sky toward the future of humanity—space (McCurdy, 2011). Although two enormous superpowers competed to prove which political system could yield better progress, the Space Race was perceived very differently from the nuclear arms race simultaneously going on, even though one could not have been achieved without the other. They represented two trajectories of the same future, one that promised both immense transformation and catastrophic collapse. The looming, and seemingly inevitable, shadow of extinction we face today is the potent combination of ecological erosion, accelerating climate change, and aggressive contamination of our air and water by our energy and waste. Like the Doomsday Clock that counted-down Mutual Assured Destruction (Boylan, Brennan, and Kahn, 1972), the best experts in the world have now set our civilization's timer to 30 years. The ticking in the form of today's news and media is so loud, it suppresses the voices of gradual progress (Pinker, 2018) since Neil Armstrong and Buzz Aldrin stepped onto the Moon. In the United States, homicides are down from 8.5/100K to 5.3/100K, poverty has dropped from 12% to 7%, and emissions have been reduced from 35M tons PM to 21M tons PM. Globally, there are now 12 wars instead of 23, 60 autocracies instead of 85, 10% extreme poverty verses 37%, and 10,325 nuclear arms from 60,780. Pinker is considered "a bit happy" by intellectuals, but we can let the data speak for itself. Life, health, sustenance, prosperity, peace, freedom, safety, knowledge, leisure, and happiness are all measurable, and over time have improved, suggesting perhaps a world that, if not transformational, is at least on an upward continuation. Once again, we find a contradiction—at the same time we are killing our enviromment, we have made steady advancements to the human condition.

If we simplify this idea of multiple seemingly contradictory trajectories into the model represented by our board game, we can imagine the following scenario. Our Farming, Arboretum, Fusion Power, and Water tiles run unsustainably at Level I to support the growing capacity of the colony. Reinventing these has been deprioritized in favor of driving Expeditionary, Information Network, and Medical tiles to Level IV. But these advancements require the support of Anti-ballistics, Enforcement, and Governance at Level III. By

necessity, Food Storage, Power Storage, and Waste Renewal have received marginal bumps to Level II, almost concessionary to appease population demands. Several threats exact their tolls on the system—Energy Demand, Water Contamination, Food Runway, and Political Fragmentation. This colony seems ostensibly imperfect and dinstinctly recognizable. It is neither completely transformational, nor on a collision course with destruction, but instead is a future where all four trajectories exist simultaneously and polyrhythmically. These trajectories can diverge, converge, and change, depending on where we move our resources, and by the limits of our capacity, they must take turns to progress. What is crucial, is the intentional and purposeful investment toward progress. Time, inertia, and competition will always be necessary balancing forces. However faster is not always better when the journey of advancement is not a straight line.

We acknowledge the deliberate similarity of these analogies between the game and reality. Although the framework was designed with these comparisons in mind, the rules of engagement are bound to the game's rationality. The benefit though that a model provides is the ability to manipulate the constructs, test their causal effects, and quantify the outcomes beyond theory alone. Doing so has allowed us to demonstrate that futures may be far more fragmented and mutable, consisting of multiple components with different trajectories that each require intervention through resources and effort. When the whole is considered by its parts, then perhaps the insurmountable challenge of circumventing collapse may not be as epic and impossible as it seems.

Limitations of the study

As we were only able to conduct three play sessions with limited range of players, the sample size of the data collected and analyzed was relatively small. Consequently, it would be difficult at this stage for the study to fully substantiate its proposed theories about the physical nature of time without further rigor, except to suggest some initial evidence has been observed through the research framework. Since the game is a simulation and bounded to its own rationality, the patterns demonstrated by the data do not reflect the scale of amplitude, velocity, and inflection represented by the vastly more complex real-world. Instead, we consider the framework to be more suitable for applications that test organizational decision-making, such as candidate selection and leadership evaluation.

Theoretical and practical implications and contribution to the field of strategic foresight

Proving qualities about the physical nature of space and time are grand scientific and mathematical endeavors outside the expertise of this study. However, the domain of systemic design and strategic foresight—specifically the use of systems and design thinking in the practice of strategic foresight as tools for yielding innovation—largely concerns the human factors of our interaction with reality. The speculative themes and scenarios presented by the game therefore are secondary to the mechanisms of dialog it provokes, and it is in this "soft", often qualitative area, where quantification could enhance discovery. In cases where cooperation and strategy are required to produce "game changer" outcomes, this framework could offer a relatively compact, low-risk, and inexpensive option for testing organizational decision-making under different conditions and scenarios. Uncertainties and situations tailored to an organization's rationality would provide contextually relevant scenarios, while the three play modes simulate common market or industry conditions. Extinction mode demonstrates the team's activity under limited time, such as limited financial budget or urgency to launch. Flourish mode demonstrates the team's potential for highest achievement under ideal conditions. Race mode demonstrates activity under competition, such as market forces and direct competitors.

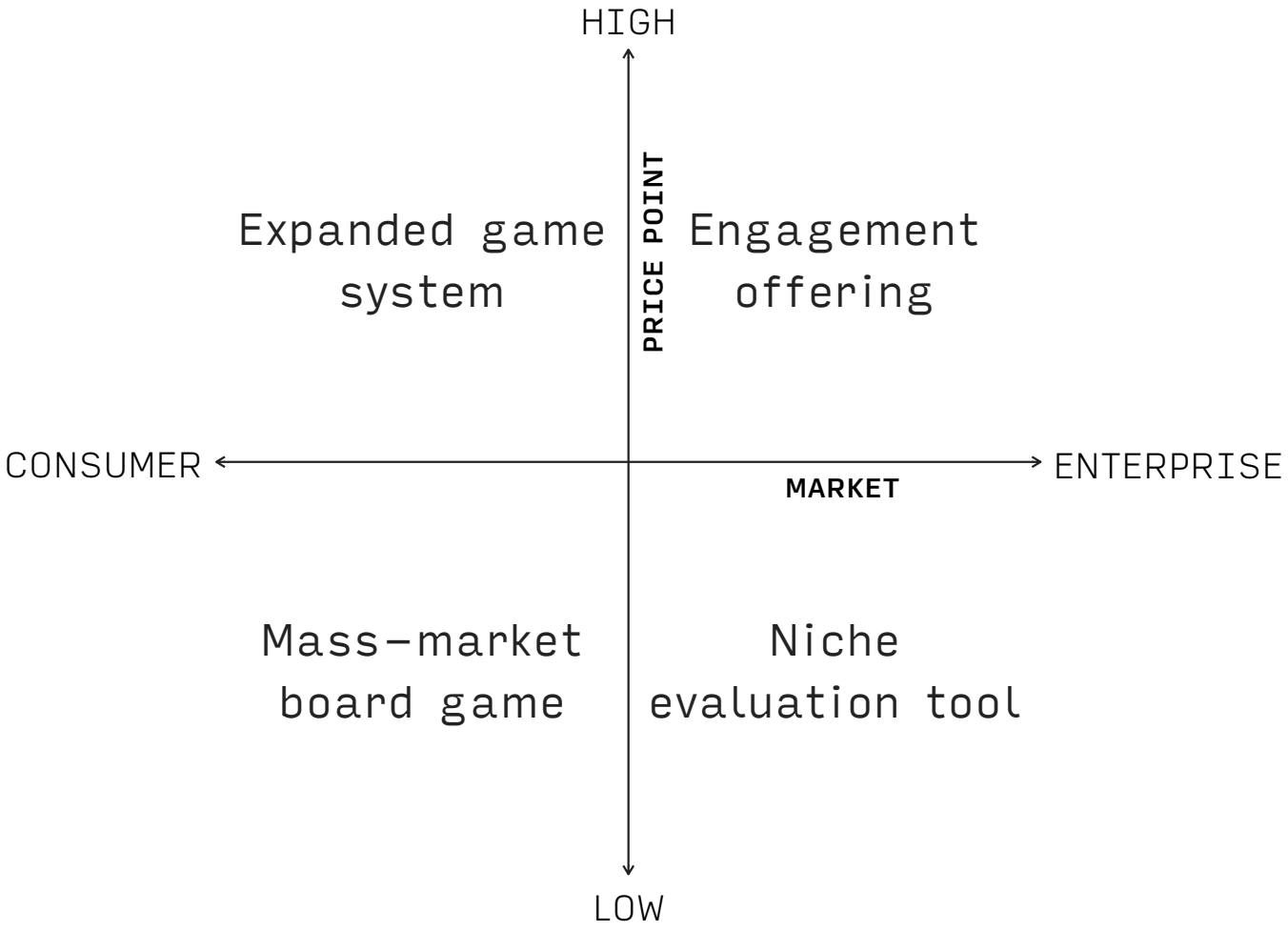
Strategic options

One of the supplementary aims of this project was to create a product or tool with market potential. Developing a business plan that proposes a viable revenue generating strategy would be a critical next phase. As an initial step toward this, we have identified advantages and challenges of four strategic options on a 2×2 that uses market (consumer vs. enterprise) and price point (low vs. high) as dimensions.

MASS MARKET BOARD GAME

Table 19. Mass market board game

ADVANTAGES	CHALLENGES
• Low barrier-to-entry. • Easily reach mass market via online sales channels, e.g. Shopify, Amazon. • Relatively low startup investment.	• Crowded market makes visibility difficult. • Need to reach economies of scale.



↑
Fig 33. Strategic options: 2×2 revealing 4 potential strategic options for the game beyond this study.

Publishing the board game for consumer market is an obvious option. Since research and development of the *minimum viable product* (in this case the game) constituted a significant component of our project, and would have been the biggest portion of startup investment required, getting to market is now a relatively low barrier. On-demand manufacturing can be achieved at a cost of approximately CAN$15.00 per set, while retail sale price at market parity between US$49-59.00 per set would put it within competition. Margin can be improved with volume and off-shore manufacturing, but economies of scale need to reached first. This will be hinged on investment in marketing to gain visibility in a crowded market.

EXPANDED GAME SYSTEM

Table 20. Expanded game system

ADVANTAGES	CHALLENGES
• Build on existing platform. • Repeat revenue from customer base. • Evergreen play experience.	• Creative talent needed to design expansion packs. • Build brand recognition.

The board game is designed as a system that can be extended thematically through *expansion packs*, e.g. "alien invasion pack", "bio-hazard pack", "civil war pack", etc. These packs bring new content and scenarios to the game and keep the play experience evergreen. This option builds on the mass market board game by increasing revenue per customer at a retail price range of US$9-29.00 per pack. Investment into developing new expansion packs would require creative talent, as well as continued marketing to grow brand recognition.

NICHE EVALUATION TOOL

Table 21. Niche evaluation tool

ADVANTAGES	CHALLENGES
• License or subscription model. • Compact, low-risk, inexpensive tool for organizations. • High niche value for specific uses.	• Relatively small market segment. • Infrastructure for self-serve model. • Earn business credibility.

Lifting directly off the framework and methodology from this project, the game offers organizations a compact, low-risk, and inexpensive interactive tool for modeling scenarios that test aptitude, especially initiatives requiring stakeholder decision-making with large scale developmental trajectories. The thematic concepts in Lunar or Martian colony development would be familiar to city planning and transportation infrastructure, and could either be represented analogously or literally by industry-specific uncertainties and situations. With threat cards mimicking risk scenarios closer to their Lunar 2024 missions, NASA for example, could use the game as part of their astronaut candidate selection process to evaluate crew temperament. This market segment however may be relatively niche, and since the cost for licensing the tool needs to be low, investment into enabling a self-serve model will be key to viability. Accreditation will also be necessary to assure data produced by the tool is admissable.

ENGAGEMENT OFFERING

Table 22. Engagement offering

ADVANTAGES	CHALLENGES
• Can be an innovative market differentiator. • High price point means lower volume sales. • Platform for building a compelling consulting practice.	• Automate data capture tools. • Time commitment for client acquisition and service. • Intellectual property protection.

The framework can also be packaged as a differentiated Design Action Research offering for modeling enterprise futures. The engagement would entail a phase during which we co-create a set of risk scenarios with clients, then facilitate play sessions in all three modes (Extinction, Flourish, and Race) to test outcomes under different conditions. Collected data would be codified into a comprehensive report. An electronic tool, such as a smartphone or tablet app, that automates data capture through image recognition and AR (augmented reality) would be a key investment, as well as protecting the intellectual property of the framework (patentable processes). A considerable time commitment to building a consulting practice would be necessary though.

Strategic fit and next steps

These strategic options are not necessarily exclusive, however suitability will depend on a capabilities analysis to determine strategic fit. A capabilities map can help match our current ability to support a strategy, and identify competencies that need to be developed if we are to pursue additional strategies. A Business Model Canvas (Osterwalder, 2011) will further close gaps in the operational and financial design of the venture. Finally, an initial three-year business plan should be proposed.

The authors

Navinder Matharu

Navinder (Nav) Matharu is a banking executive with over 15 years experience. He has held various roles in Personal Banking, Business Banking and Wealth Distribution. The majority of Navinder's career has centred on the customer experience and driving strong financial performance. Recently, Navinder has taken on roles that have focused on change management and currently he is developing and executing strategies focused on efficiency and sales growth.Navinder has a Bachelor degree in Mathematics from Carlton University. The Master of Design in Strategic Foresight and Innovation from OCAD University has augmented Navinder's capabilities by providing new tools, methods, and perspectives.

Navinder and his wife are the proud parents of two very active young boys. In his spare time, Navinder enjoys spending quality time with the family, trying new experiences, reading and hiking.

Adam Oliveira

A lifetime playing at the front of technology waves, Adam has designed for tech as a co-founder, creative director, and practice lead. He was a founding design lead at IBM's MobileFirst partnership with Apple, and now leads Planning Analytics with IBM's Hybrid Cloud. Much of his work with clients has been to envision the future state of their products and services, and use design methods to develop practical strategies that take them from here to there. The Master of Design in Strategic Foresight and Innovation from OCAD University has been a natural complement to this practice, bringing disciplined approaches and techniques to speculative domains.

He lives in Toronto with his wife and two children, who seem to appreciate (or tolerate), an over-imaginative father and husband. In his spare time, he invents board games that explore systems and foresight concepts.

Bibliography

Design

Escobar, A. (2012, October). Notes on the Ontology of Design. In Sawyer Seminar, Indigenous Cosmopolitics: Dialogues about the Reconstitution of Worlds, organized by Marisol de La Cadena and Mario Blaser, October (Vol. 30).

Norman, D. (1988). The design of everyday things. New York: Basic Books.

Osterwalder, A., Pigneur, Y., Oliveira, M. A. Y., & Ferreira, J. J. P. (2011). Business Model Generation: A handbook for visionaries, game changers and challengers. African journal of business management, 5(7), 22–30.

Osterwalder, A., Pigneur, Y., Bernarda, G., & Smith, A. (2014). Value proposition design: How to create products and services customers want. John Wiley & Sons.

Schumpeter, J. (1942). Creative destruction. Capitalism, socialism and democracy, 825.

Winograd, T., Flores, F., & Flores, F. F. (1986). Understanding computers and cognition: A new foundation for design. Intellect Books.

Fiction

Heinlein, R. A. (1991). Stranger in a Strange Land. 1961. New York: Ace.

Niccol, A. (1997). Gattaca.

Foresight

Almy, B. & Cicchetti, D. (2018). Equifinality versus multifinality. In M. Bornstein (Ed.), The SAGE encyclopedia of lifespan human development (pp. 764–765). Thousand Oaks,, CA: SAGE Publications, Inc. doi: 10.4135/9781506307633.n285.

Bishop, P. ,Hines, A., Collins, T. (2007) Current State of Scenario Development: an overview of techniques. Foresight Vol. 9 No. 1 pp 5–25 Emerald Group Publishing.

Dator, J. (2009). Alternative futures at the Manoa School. Journal of Futures Studies, 14(2), 1–18.

Dator, J. (2017). Manoa's four generic images of the futures. Association of Professional Futurists Compass pg 2–6.

Geach, P. (1977). Providence and evil: the Stanton lectures 1971–2. CUP Archive. 1971–2. CUP Archive, 1977

Hodgson, T & Sharpe, B. (2007) Deepening Futures with System Structure. Scenarios for Success: Turning Insight into Action Chapter 5 (pp 121 – 143) John Wiley & sons, Ltd.

Inayatullah, S. (1998). Causal layered analysis: Poststructuralism as method. Futures, 30(8), 815–829.

Lum, R. A. K.(2016) 4 Steps to the Future: A Quick and Clean Guide to Creating Foresight. FutureScribe.

Moyer, C. A. (2015). Timelines and quantum time operators. Foundations of Physics, 45(4), 382–403.

Pinker, S. (2018). Is the world getting better or worse? A look at the numbers. TED. https://www.ted.com/talks/steven_pinker_is_the_world_getting_better_or_worse_a_look_at_the_numbers?language=en

Sharp, B. (2013) Three Horizons: The Patterning of Hope. Triarchy Press UK.

Todd, P. (2016). On behalf of a mutable future. Synthese, 193(7), 2077–2095.

Van der Heijden, K. (1997). Scenarios, strategies and the strategy process.

Voros, J. (2003) A generic foresight process framework. foresight 5,3 2003, pp. 10–21 MCB UP Limited, 1463–6689.

Games

Brandt, E. (2006, August). Designing exploratory design games: a framework for participation in Participatory Design. In Proceedings of the ninth conference on Participatory design: Expanding boundaries in design–Volume 1 (pp. 57–66). ACM.

Brandt, E., & Messeter, J. (2004, July). Facilitating collaboration through design games. In Proceedings of the eighth conference on Participatory design: Artful integration: interweaving media, materials and practices–Volume 1 (pp. 121–131). ACM.

Brandt, E., Messeter, J., & Binder, T. (2008). Formatting design dialogues–games and participation. Co-Design, 4(1), 51–64.

Carse, J. (2011). Finite and infinite games. Simon and Schuster.

Luce, R. D., & Raiffa, H. (2012). Games and decisions: Introduction and critical survey. Courier Corporation.

McGonigal, J. (2003). 'This Is Not a Game': Immersive Aesthetics and Collective Play. In MelbourneDAC: 5th International Digital Arts and Culture Conference. Melbourne.

McGonigal, J. (Feb 2010). Gaming can make a better world. TED: Ideas worth spreading. https://www.ted.com/talks/jane_mcgonigal_gaming_can_make_a_better_world

Vaajakallio, K., & Mattelmäki, T. (2014). Design games in codesign: as a tool, a mindset and a structure. CoDesign, 10(1), 63–77.

Xu, Y., Barba, E., Radu, I., Gandy, M., & MacIntyre, B. (2011). Chores Are Fun: Understanding Social Play in Board Games for Digital Tabletop Game Design. In DiGRA Conference.

Human factors

Cohen, W., Levinthal, D (1990). Absorptive Capacity: A New Perspective on Learning and Innovation. In Administrative Science Quarterly, Vol 35, No1, Special Issue: Technology, Organization, and Innovation pp. 128–152.

Economist (2009). Guru: Herbert Simon http:// www.economist.com/node/13350892

Gigerenzer, G., Shelten, R. (2002). Bounded Rationality: the adaptive toolbox. Cambridge, MA:MIT Press

Simon, H. A. (1991). Bounded rationality and organizational learning. Organization science, 2(1), 125–134.

Research methods

Fonesca, R. B. (2013). Action research applied to design of environmental educational games. SBC — Proceedings of SBGames. Art and design track.

Fullerton, T. (2018). Game design workshop: a playcentric approach to creating innovative games. AK Peters/CRC Press.

Sein, M., Henfridsson, O., Purao, S., Rossi, M., & Lindgren, R. (2011). Action design research. Management Information Systems Quarterly, 35(1), 37–56.

Swann, C. (2002). Action research and the practice of design. Design issues, 18(1), 49–61.

Sociology

Clark, Liesl (Feb 2000). "Polynesia's Genius Navigators". Retrieved 17 November 2016.

Forbes, Robert James (1993). Studies in ancient technology, Volume 2. Brill. p. 146. ISBN 978-90-04-00622-5.

Grossman, D. (2018, April 19). Political Tensions Could Rob the U.S. of the Russian Rocket Engine It Desperately Needs. Retrieved from https://www.popularmechanics.com/space/rockets/a19852684/political-tensions-threaten-us-use-of-russia n-rocket-engine/

Krulwich, R. (2013, December 10). What Happened On Easter Island — A New (Even Scarier) Scenario. Retrieved from https://www.npr.org/sections/krulwich/2013/12/09/249728994/what-happened-on-easter-island-a-new-even-scarier-scenario

Kremer, M. (1993). "Population Growth and Technological Change: One Million B.C. To 1990" (PDF). The Quarterly Journal of Economics. 108 (3): 681–716. doi:10.2307/2118405. JSTOR 2118405.

Kritz, M. M., Lim, L. L., & Zlotnik, H. (1992). International migration systems: a global approach.

Malthus, T. R. (1888). An essay on the principle of population: or, A view of its past and present effects on human happiness. Reeves & Turner.

Morris, Ian (2010). Why the West Rules—For Now. New York: Farrar, Straus and Giroux. ISBN 978-0-374-29002-3.

Sawyer, Peter Hayes (1997). The Oxford Illustrated History of the Vikings. ISBN 0-19-820526-0.

Taagepera, Rein (1979). "Size and Duration of Empires: Growth–Decline Curves, 600 BC to 600 AD". Social Science History. Social Science History, Vol. 3, No. 3/4. 3 (3/4): 115–138 [125]. doi:10.2307/1170959. JSTOR 1170959

Williams, R. (1977). Marxism and literature (Vol. 1)., pgs 75–82. Oxford Paperbacks.

Space

Abadie, L.J., Lloyd, C.W., Shelhamer, M. J. (Dec 2017). The Human Body in Space: Gravity, Who Needs It? NASA Studies Your Body in Space. Retrieved from https://www.nasa.gov/hrp/bodyinspace

Anatoly Zak (2015). "Sputnik's mission". RussianSpaceWeb.com. Anatoly Zak. Retrieved 27 December 2015.

Bin, C. (1997). Part III United Nations Treaties on Outer Space, 9 The 1967 Space Treaty. Studies in International Space Law. doi:10.1093/law/9780198257301.003.0010

CSIS, "The U.S. Military and Commercial Space Industry," (Oct 2016). Retrieved from https://www.csis.org/events/us-military-and-commercial-space-industry.

COSPAR Panel on Exploration Report (Jun 2010). Toward a Global Space Exploration Program: A Stepping Stone Approach Committee On Space Research (COSPAR) COSPAR Panel on Exploration (PEX) (80 pp) Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.367.5618&rep=rep1&type=pdf

Correia, M. J. (1998). Neuronal plasticity: adaptation and readaptation to the environment of space. Brain research reviews, 28(1–2), 61–65.

Davies, T. P., Johnson, S. D., Braithwaite, A., & Marchione, E. (2016). Space–Time Analysis of Point Patterns in Crime and Security Events. Approaches to Geo–mathematical Modelling,127–150. doi:10.1002/9781118937426.ch8

Dwayne, A. Day (2005–11–28)." Boldly Going: Star Trek and spaceflight. The Space Review.

Choi, Charles Q. (Oct 2015). If Humans Go To Mars, Where's The Best Place To Land? Popular Science. https://www.popsci.com/if-humans-go-to-mars-wheres-best-place-to-land

Day, D. A. (1996). Invitation to Struggle: The History of Civilian–Military Relations in Space. Exploring the Unknown: Selected Documents in the History of the US. Civil Space Program, 2.

Davies, T. P., Johnson, S. D., Braithwaite, A., & Marchione, E. (2016). Space–Time Analysis of Point Patterns in Crime and Security Events. Approaches to Geo–mathematical Modelling,127–150. doi:10.1002/9781118937426.ch8

Dickerson, K. (Oct 2015). Here's why NASA won't work with China to explore space. Business Insider. Retreived from http://www.businessinsider.com/nasa-china-collaboration-illegal-2015-10.

E. (n.d.). Building Galileo. Retrieved March 02, 2018, from https://www.esa.int/Our_Activities/Navigation/Galileo/Building_Galileo

Einstein, Albert (1917). "Kosmologische Betrachtungen zur allgemeinen Relativitätstheorie". Sitzungs. König. Preuss. Akad.: Sitzungsb. König. Preuss. Akad. 142–152.

Hampson, J. (Jan 2017). The Future of Space Commercialization. Retrieved from https://science.house.gov/sites/republicans.science.house.gov/files/documents/TheFutureofSpaceCommercializationFinal.pdf

Heisenberg, W. (1949). The physical principles of the quantum theory. Courier Corporation.

History of Space Travel (compiled 2018, January). https://airtable.com/shrI9hrH8YbsNXxnU

Hitchens, T. (2014). Space Security–Relevant International Organizations: UN, ITU, and ISO*. Handbook of Space Security, 507–520. doi:10.1007/978-1-4614-2029-3_19

Hollingham, R. (Oct 2014). Five steps to colonizing Mars. From World–Changing Ideas. http://www.bbc.com/future/story/20141030-five-steps-to-colonising-mars

Hollingham, R. (Nov 2014). Five ways to become an astronaut. Retrieved from http://www.bbc.com/future/story/20130510-five-ways-to-become-an-astronaut

Howell, E. (Jun 2017). How To Become An Astronaut. https://www.space.com/25786-how-to-become-an-astronaut.html

Ives, B. Moving To Mars: Mankind's Next Home.

Lambakis, S. (2017). Foreign Space Capabilities: Implications for U.S. National Security (Rep.). Fairfax, VA: National Institute Press.

Leckie, A. (Feb 2016). The 12 Greatest Challenges for Space Exploration. Wired. Retrieved from https://www.wired.com/2016/02/space-is-cold-vast-and-deadly-humans-will-explore-it-anyway/

Kranz, G. (2001). Failure is not an option: Mission control from Mercury to Apollo 13 and beyond. Simon and Schuster.

Mailonline, H. P. (Jan 2018). Virgin Galactic will send tourists into space within MONTHS: Richard Branson's VSS Unity spaceplane completes another successful glide test 3 years after the firm's deadly crash. Retrieved February 25, 2018, from http://www.dailymail.co.uk/sciencetech/article-5261965/Virgin-Galactic-set-send-tourists-space-YEAR.html

Marshall, W.S., Moltz, J.C. (Jan 2009). 9 Ways NASA Can Tackle Climate Change Retrieved from https://www.scientificamerican.com/article/nasa-and-climate-change/

McCurdy, H. E. (2011). Space and the American imagination. JHU Press.

McKay, C. P., Toon, O. B., & Kasting, J. F. (1991). Making Mars habitable. Nature, 352(6335), 489.

Moltz, J. C. (2010). Space and Strategy: A Conceptual versus Policy Analysis. Astropolitics, 8(2), 113-136. doi:10.1080/14777622.2010.522935

Moltz, J. C. (2003). New challenges in missile proliferation, missile defense, and space security. Monterey, CA: CNS.

Mortillaro, N. (2018, February, 07). SpaceX launches powerful Falcon Heavy rocket. CBC News| Technology & Science Retrieved from http://www.cbc.ca/news/technology/spacex-falcon-heavy-launch-1.4520242

NASA (Aug 2017). Sunset on Mars. https://www.nasa.gov/multimedia/imagegallery/image_feature_347.html

NASA: Apollo's Legacy Is NASA's Future. https://www.nasa.gov/specials/apollo50th/back.html

NASA Astronaut Selection. https://astronauts.nasa.gov/content/broch00.htm

NASA. The Global Exploration Strategy:The Framework for Coordination (n.d.). Retrieved from https://www.nasa.gov/pdf/296751main_GES_framework.pdf

Onley, Robert David (2013) Death from above – The Weaponization of Space and the Threat to International Humanitarian Law, 78 J. Air L. & Com. 739

Orloff, Richard W. (Sep 2004) [First published 2000]. "Table of Contents". Apollo by the Numbers: A Statistical Reference. NASA History Division, Office of Policy and Plans. NASA History Series. Washington, D.C.: NASA. ISBN 0-16-050631-X. LCCN 00061677. NASA SP-2000-4029. Retrieved June 12, 2013.

POMPIDOU, A. (Apr 2000). THE ETHICS OF SPACE POLICY. Retrieved from http://unesdoc.unesco.org/images/0012/001206/120681e.pdf

Primack, J. R. (n.d.). Protecting the Space Environment for Astronomy. Preservation of Near-Earth Space for Future Generations, 71-76. doi:10.1017/cbo9780511564925.007

Q. (Sep 2016). Is There A Fortune To Be Made On Mars? Retrieved April 15, 2018, from https://www.forbes.com/sites/quora/2016/09/26/is-there-a-fortune-to-be-made-on-mars/#5f0237fe6e28

Rainey, K. (Aug 2015). Crew Members Sample Leafy Greens Grown on Space Station. Retrieved February 25, 2018, from https://www.nasa.gov/mission_pages/station/research/news/meals_ready_to_eat/

Roberts A. (2016) Golden Age SF: 1940–1960. In: The History of Science Fiction. Palgrave Histories of Literature. Palgrave Macmillan, London

Rummel, J. D., Race, M. S., & Horneck, and the Princeton Workshop Participants, G. (2012). Ethical considerations for planetary protection in space exploration: a workshop. Retrieved from https://www.liebertpub.com/doi/pdf/10.1089/ast.2012.0891

Sagan, C. (1997). Pale blue dot: A vision of the human future in space. Random House Digital, Inc.

Scharf, Caleb A. (Sep 2016). So you want to terraform Mars? Scientific American. https://blogs.scientificamerican.com/life-unbounded/so-you-want-to-terraform-mars/

Scoles, S. (Aug 2017). The Space Junk Problem Is About to Get a Whole Lot Gnarlier. Retrieved March 02, 2018, from https://www.wired.com/story/the-space-junk-problem-is-about-to-get-a-whole-lot-gnarlier/

Siegel, E. (Dec 2017). Sorry America, we're not going back to the moon. Forbes, Science. https://www.forbes.com/sites/startswithabang/2017/12/19/sorry-america-were-not-going-back-to-the-moon/#6dd1e4822a5c

Spin-off technologies from the Space Program. https://spinoff.nasa.gov/flyers/apollo.htm

United Nations Office for Outer Space Affairs (May 2005). SPACE SOLUTIONS for the World's Problems: How the United Nations family uses space technology for achieving development goals, Retrieved from http://www.unoosa.org/pdf/publications/IAM2005E.pdf

White, R. J., & Averner, M. (2001). Humans in space. Nature, 409(6823), 1115.

Wiles, J. (Sep 2013) Why We Explore: Beyond Earth, Expanding the Human Presence Into the Solar System. Retrieved from https://www.nasa.gov/exploration/whyweexplore/why_we_explore_main.html#.WmqTjqinE2w

Wilford, G. (2017, August 19). Nasa plans to make oxygen from atmosphere on Mars. Retrieved February 25, 2018, from http://www.independent.co.uk/news/science/mars-nasa-2020-rover-oxygen-microorganism-algae-bacteria-robert-lightfoot-moon-international-space-a7902531.html

Zubrin, R. (n.d.). The Economic Viability of Mars Colonization. Retrieved April 15, 2018, from http://www.aleph.se/Trans/Tech/Space/mars.html

Strategy

Aumann, R. J. (2017). Game theory. The New Palgrave Dictionary of Economics, 1-40 Boylon, E., D. Brennan, and G. Kahn. "An analysis of assured destruction." Boylon et al. NY (1972).

Hur, J. (2017, September 05). History of Entrepreneurship. Retrieved February 27, 2018, from https://bebusinessed.com/history/history-of-entrepreneurship/

Johnson, R. (1997). Nuclear arms control through multilateral negotiations. Contemporary Security Policy, 18(2), 83-115. doi:10.1080/13523269708404163 Juma, C. (2016). Innovation and its Enemies.

Leyton-Brown, K., & Shoham, Y. (2010). Essentials of game theory: A concise, multidisciplinary introduction. San Rafael, Calif: Morgan & Claypool.

Williams, J. D. (1966). The Compleat Strategyst: Being a primer on the theory of games of strategy. Courier Corporation.

Systems

Ackoff, R. L., & Emery, F. E. (2013). On purposeful systems: An interdisciplinary analysis of individual and social behavior as a system of purposeful events. New Brunswick, NJ: Aldine Transaction.

Ashby, W. R., & Goldstein, J. (2011). Variety, constraint, and the law of requisite variety. Emergence: Complexity and Organization, 13(1/2), 190.

Checkland, P. (1999). Soft systems methodology: A 30-year retrospective. Chichester: John Wiley.

Christakis, N. A. (2014). Social Systems and Design. Translational Systems Sciences,58. doi:10.1007/978-4-431-54478-4

Gharajedaghi, J. (2011). Systems thinking: Managing chaos and complexity: A platform for designing business architecture. Elsevier.

Ivanov, K. (1991). Critical systems thinking and information technology: Some summary reflections, doubts, and hopes through critical thinking critically considered, and through hypersystems. Journal of Applied Systems Analysis, 18, 39–55.

Narayanan, A., Bonneau, J., Felten, E., Miller, A., & Goldfeder, S. (2016). Bitcoin and Cryptocurrency Technologies: A Comprehensive Introduction. Princeton University Press.

Schaller, R. R. (1997). Moore's law: past, present and future. IEEE spectrum, 34(6), 52–59. Retrieved from http://mprc.pku.edu.cn/courses/organization/autumn2013/paper/Moore's%20Law/Moore's%20law%20past,%20present%20and%20future.pdf

Sweeney, L. B., & Meadows, D. (2010). The systems thinking playbook: Exercises to stretch and build learning and systems thinking capabilities. Chelsea Green Publishing

Warfield, J. N., & Perino, G. H. (1999). The problematique: Evolution of an idea. Systems Research and Behavioral Science,16(3), 221-226. doi:10.1002/(sici)1099-1743(199905/06)16:33.0.co;2-g