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Keeping up shared infrastructure on a Port of Mars: An experimental study

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Abstract

In this study, we present a new game, Port of Mars, that allows for the study of collective action in extreme environments. The game is situated in the first-generation habitat on Mars, to provide an engaging narrative of a collective action problem under high uncertainty. This pilot study finds that most groups are able to avoid the collapse of the habitat and that the existence of thresholds makes groups risk-averse. The game demonstrates the initial outcomes of a transdisciplinary project that could provide new ways of studying governing the commons under high uncertainty, and a potential educational game for coping with commons dilemmas.

Introduction

Research showing how communities overcome conflicts related to shared resource problems is substantial (Ostrom, 1990). There is a wealth of knowledge about how small communities successfully manage shared resources in relatively stable environments. This research is vital, but we face an urgent need to broaden our investigations, because in the present age of threats to the well-being of our species, and to the biosphere more broadly, we depend directly and indirectly on the actions of billions of others.

The notion of the “Anthropocene” expresses a recognition that human activities have become a dominant driver of Earth’s systems (Crutzen, 2006, Steffen et al. 2007). Future well-being and stability of planet-wide ecosystems across several dimensions—climatic, economic, social, biological, and others—require that humans effectively navigate Collective Risk Social Dilemmas (Milinkski et al. 2008). The stakes of avoiding tipping points of Earth’s dynamic systems are astronomical, and the costs of failure dire. It is with these sobering challenges in mind that we crafted the narrative frame for our game-based experiment, Port of Mars. In this game, players must keep a small group of people alive in the unforgivingly harsh conditions of Mars.

Space exploration metaphors are not at odds with the discourse on sustainable use of shared terrestrial resources. Economist Kenneth E. Boulding (1966) invoked the concept of “Spaceship Earth” to describe the perspective necessary to cope with increasing environmental challenges. He contrasted this perspective with what he called “Cowboy economics,” which assumes a world of limitless resources. For the “cowboy economist,” when a region’s resources are depleted, one simply moves on to a new region. This perspective embraces endless production and consumption, as well as the regular exploration and exploitation of new territories needed to fuel it. Yet this logic has produced negative and dangerous impacts on environments and resources. As a result of this logic, we have likely passed some critical planetary thresholds (Rockström et al. 2009). Our present situation requires a shift to “Spaceperson economics” that accounts for the reality of limited resources, the negative impacts of limitless production—e.g., pollution, CO₂ emissions, biodiversity loss, etc.—and the urgent need for sustainable solutions.

A fictional Martian community provides a useful setting to consider analogous challenges. What is the core commons dilemma for a settlement on Mars and how is it different from communities on planet Earth? The hazardous Martian environment leaves very little room for errors in resource management. When humans arrive on Mars, they will encounter a broad variety of resource, technological, psychological, and social challenges. Since the inhabitants will be entirely reliant on one another, they must work collectively to make decisions and take actions that will keep their community alive and prospering. The Red Planet is not conducive to human life; there are many ways to die on Mars. Habitats must be kept in good repair to provide protection from radiation and the harsh Martian environment. Food must be grown, energy produced, and water harvested from ice deposits. Citizens of Mars will live in complete isolation, with no real-time communication with Earth possible due to the limits of the speed of light.

In spite of these technical challenges, the social aspects of inhabiting Mars might prove to be the greatest challenge of all. Everyone will have to work together constantly to ensure the health and safety of the habitat, with life-or-death consequences. Nearly all resources will be shared, extremely limited, and must therefore be managed with the

utmost care. There is no option of moving to a new region if resources become depleted. “Cowboy economics” won’t work in space. Establishing a long-term human presence on Mars will require overcoming these social hurdles. As such, the Martian setting provides a fitting analog for investigating challenges of collective action in extreme conditions like those increasingly encountered on Earth due to climate change. The Port of Mars project is an effort to understand how to best approach situations that require human cooperation to navigate hazardous conditions, limited resources, and high uncertainty.

We acknowledge the game involves a degree of speculation. We cannot fully create a Martian experience for players, only an imaginative one built on narrative and other representations. At its core, Port of Mars is based on the structures of traditional games used in commons dilemmas research. These structures are wrapped in a vivid narrative of an early Martian community. Like other commons dilemma games, if the shared infrastructure and resources are not managed effectively, there is no payoff for the players. In our Martian fiction, this means a catastrophic failure of the community and death to all its members.

In the next section, we present our experimental design. Then we discuss the implementation and our results. The paper finishes with some conclusions and descriptions of future research.

Experimental Design

Port of Mars was created over the course of two years by a transdisciplinary team of artists, game designers, planetary scientists, sustainability scientists, and education specialists. The project is part of Arizona State University’s Interplanetary Initiative, a pan-university effort to design and build the future of human space exploration. Set in the near future during the early years of the first human community on Mars, Port of Mars is a resource allocation game examining how people navigate conflicts between individual goals and common interests relative to shared resources. It presents a socially competitive environment in which the survival of the population is constantly in peril. Unexpected events occur regularly. Severely limited resources and deadly conditions hostile to life leave very little margin for error. Players must find ways to balance personal interests with the interest of the community. The game differs from typical commons dilemma experiments not simply for its use of a fictional Martian context, but, more importantly, for the key role uncertainty plays in-game mechanics and strategy.

The game involves five players, each of whom must decide how much of their time and effort to invest in maintaining public infrastructure and renewing shared resources and how much to expend in pursuit of their individual goals. Such a design is in line with irrigation games used to study commons dilemmas in recent years (e.g. Janssen et al., 2012; Anderies et al. 2013).

In the game, “Upkeep” is a number that represents the physical health of the community—the condition of infrastructure, production of food, water, and breathable air, radiation shielding, energy production, and other necessary resources. This number begins at 100 and goes down by twenty-five points each round, representing resource consumption and wear and tear on infrastructure. If that number reaches zero, the community collapses and everyone dies. No one wins if everyone is dead. Players take on one of five possible characters: Politician, Pioneer, Entrepreneur, Researcher, and Curator. Each player receives ten “Time Blocks” per round. These

blocks represent time-based renewable resources that characters may spend contributing to Upkeep or pursuing their own ambitions. Each Time Block spent on Upkeep raises the Upkeep number by one point.

Characters may also spend Time Blocks to purchase Influence cards. These cards represent the player's capacity to impact specific domains. There are five kinds of Influence cards: Culture, Legacy, Science, Government, and Finance. Characters can use combinations of Influence cards to purchase Accomplishment cards, representing significant achievements in their domain—e.g., scientific discoveries, cultural productions, political milestones, etc. Each Accomplishment card is worth a set number of points. Through purchasing and gathering Influence cards, then using them to purchase Accomplishment cards, players rack up points (Appendix 2). The player with the most points at the end of the game wins.

Each character specializes in a certain kind of Influence that require less time and effort to produce. For example, the Curator specializes in Culture. It costs him only two Time Blocks to produce one Culture card, whereas it costs him three Time Blocks for a Finance or Legacy card. Each character has two kinds of Influence it cannot produce. The Curator, for example, cannot produce Science or Government. In order for players to acquire types of Influence they cannot produce, they must trade with other players. Each player has a unique deck of Accomplishment cards for their character. Near the beginning of the game, each player turns over three Accomplishment cards from their deck. These are the Accomplishments available to them to purchase this round. At the end of the round, players may discard any Accomplishment cards they have not purchased, and replace them with new ones drawn from their deck.

Each player's deck consists of fourteen Accomplishment cards, each worth a varying number of points. Twelve of these must be purchased with Influence cards. Two Accomplishment cards—that participants dubbed the "dirty" cards—do not cost any Influence to purchase but instead subtract Upkeep points. Purchasing these cards earns the player points, costs them nothing, but subtracts from the collective resources and infrastructure of the community.



Figure 1: Illustrations of character roles. Illustrations by Titus Lunter.

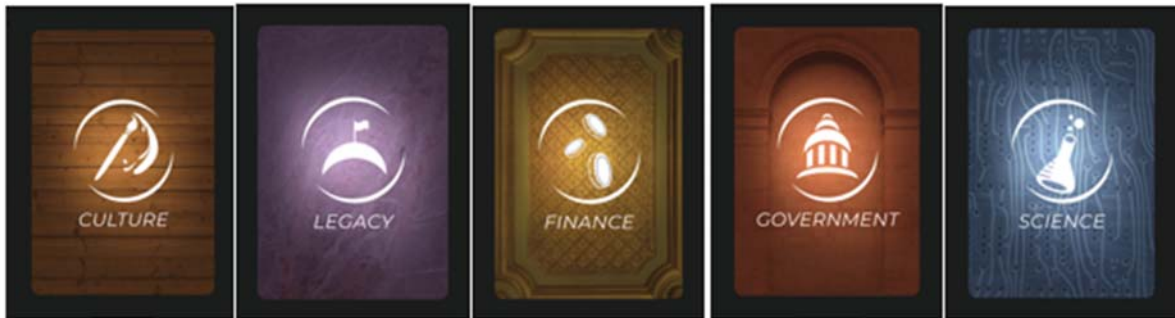


Figure 2: Influence cards. Graphic design by Liz Leo.

We introduced uncertainty into the game by means of a deck of Event cards (Appendix 1). Players draw one Event card per round (with the exception of round one, in which no Event cards are drawn). Each Event impacts players in a way that is either negative, positive, or neutral.

The game features tipping points. If the Upkeep falls below sixty-five, players draw two Event cards per round. If it falls below thirty-five, players draw three Event cards.

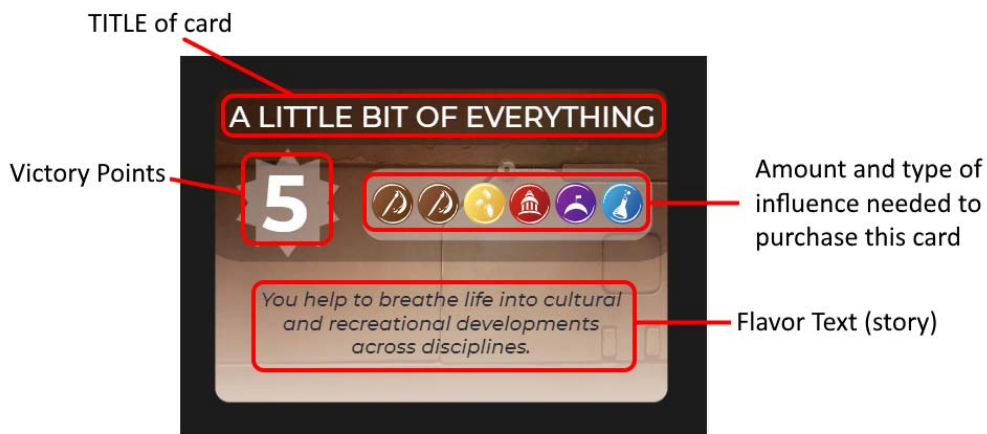


Figure 3: Accomplishment card. Graphic design by Liz Leo.

When participants arrive, they are asked to read a two-page information sheet with the rules of the game (Appendix 3). A moderator then verbally walks them through the game instructions, highlighting some key elements (Appendix 4). The moderator answers any questions the participants have, and then the first round of play begins. Players often ask questions of the moderator during the first round, as they work to navigate the mechanics and rules. Typically, after the first round, the participants have a solid understanding of the game.

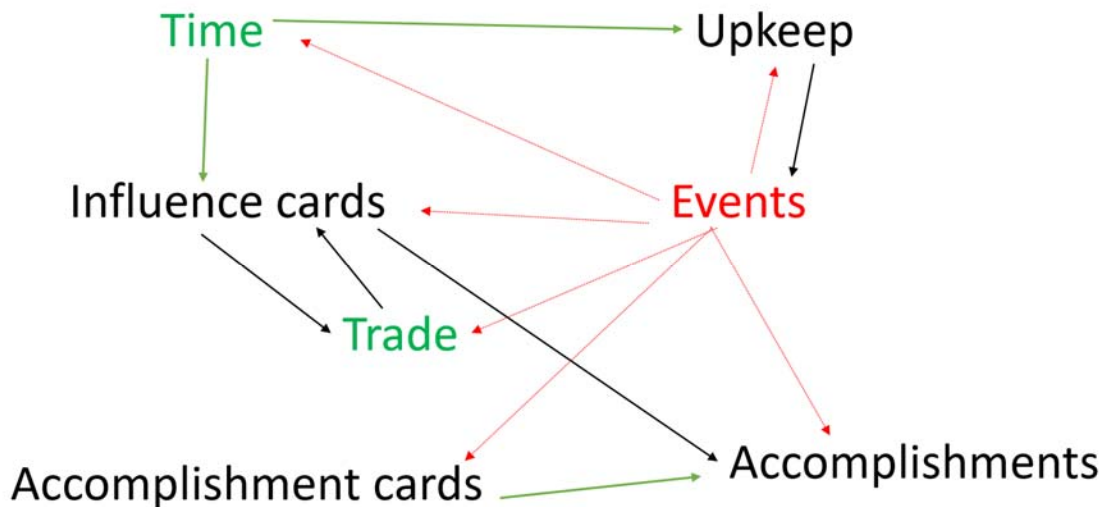


Figure 4: Schematic outline of the game. Players decide how to invest Time Blocks, how to trade, and when to buy Accomplishment cards. Event cards can impact all components of the game.

Expected outcomes

Port of Mars is too complex to calculate specific predictions like Nash equilibria. However, we used a computer simulation to explore the range of possible outcomes given some basic strategies players could use. The resulting model is a highly stylized version of the actual game.

The model requires us to make some critical assumptions, such as that players are boundedly rational and self-interested. We assume that players only invest in producing their specialty Influences, and trade with other players to acquire other needed Influence cards. We do not simulate trade but assume that players try to buy Accomplishment cards with the highest ratio of points per Time Blocks invested, and are able to buy that card if sufficient Influence cards have been acquired.

The model also assigns agents a probability, equal for each card, to discard available Accomplishment cards. The agents decide as a group how much to invest in Upkeep. The group has a target level of Upkeep to maintain during gameplay. This allows us to vary the target and investigate how this impacts outcomes.

The model assumes an agent will either use the “dirty card,” or they will not. If an agent uses a dirty card, they use it when it provides the best return on time invested. In actual gameplay, players were more strategic in using the dirty card and often saved it for when they suspected the game was close to ending. In the model, agents do not attempt to mitigate their intentions to use a dirty card by investing extra Time Blocks in Upkeep. Such a pro-active strategy would reduce the difference of consequences between simulations in which the dirty card was used and those in which it was not. We saw this pro-active strategy in some human groups, but not in others.

Figure 5 shows the fraction of groups collapsing in 1000 simulations given different target levels of Upkeep. While the use of a dirty card by an agent improves their chances of winning the game, it significantly increases the likelihood of community collapse, especially if the target level of Upkeep is below 80. Reducing the target level, while temporarily attractive, also increases the chance of the group of not surviving.

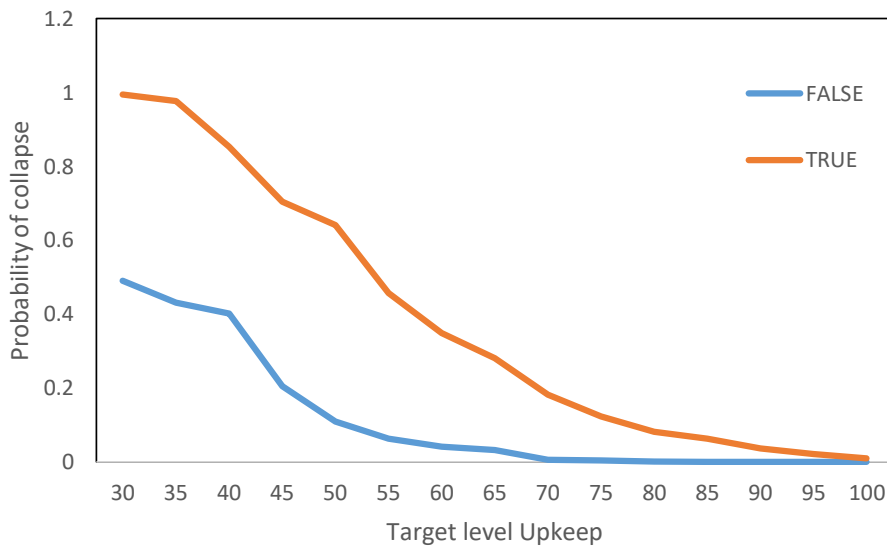


Figure 5: If agents do not use “dirty cards” (FALSE), the probability of extinction for a group remains below 50 if the target level for upkeep is 50 or higher. If agents use “dirty” cards (TRUE) this target level increases to 70.

We can evaluate the outcomes of simulated games by quantifying the costs of Event cards (see Appendix 1). For example, the Event card called “Crop Failure” costs 20 Upkeep points, and Event card “Difficult Conditions” raises the cost of Upkeep points from one to two Time Block. We can thus estimate the costs of external events in units of Time Blocks. Figure 6 shows the results for 5000 simulations with a target Upkeep of 100, and no agents using the dirty card. We see that there is a widespread of points groups can derive, but we see also that this spread is strongly related to the kind of Event cards the group drew. The number of points a group derives is not all based on skill, but strongly related to the Events they experience. As the cost of Events increases, the total number of points scored by a group decreases.

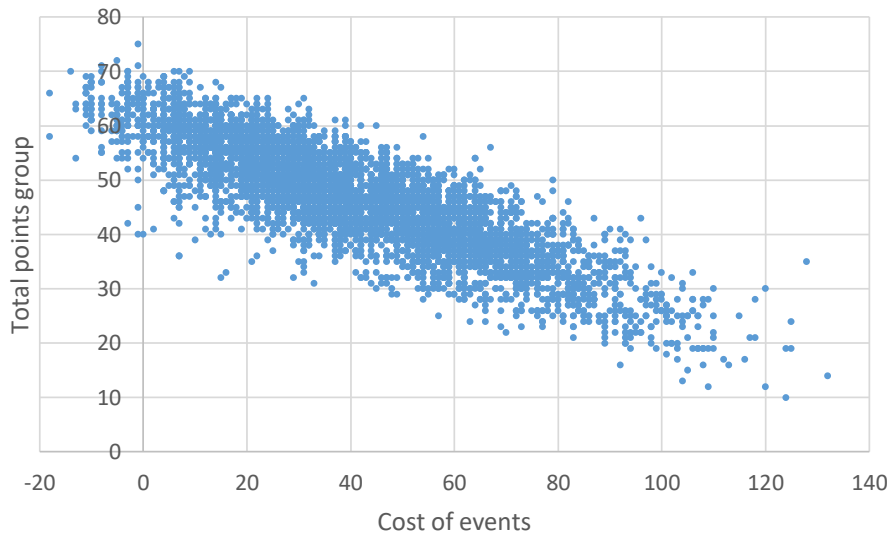


Figure 6: Relation between costs of Events and total points derived by the group after nine rounds with a target Upkeep level of 100 and not using the dirty card. The figure shows the outcome of 5000 simulated games.

Figure 7 shows the mean number of points a group derives over 5000 games for varying target levels of Upkeep both with and without the use of the dirty card. The mean level of points remains quite similar for target levels of 50 and higher. The standard deviation is largely caused by the Event cards groups experience. When the target level for Upkeep drops below 50, the frequency of groups collapsing when they use the dirty card leads to a reduction of the points groups received. Based on these simulations, the decision on the target level should be based on the probability of survival, not the expected number of points the group receives.

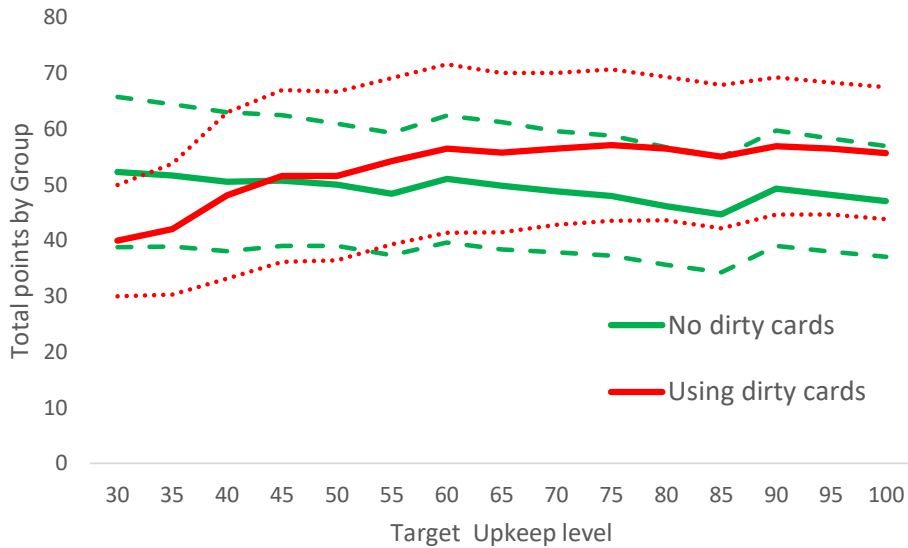


Figure 7: The relation between the target Upkeep level and the average points derived during 5000 simulated games. The dotted lines indicate the mean +/- one standard deviation.

Since players do not know the number of rounds in a game, we calculated the frequency of group surviving for different numbers of rounds. The results remain similar as in Figure 5. This suggests that keeping the Upkeep at 70 at the start of the round, which lead to an Upkeep level after wear and tear of 45 and thus receiving 2 Event cards, still keeps the probability of group collapse very low provided dirty cards are used wisely.

Results

We performed a series of experiments with the game in February, and March 2019. Nineteen groups of five undergraduate students from Arizona State University were recruited to play the game. We recruited from a database of students who signed up to participate in experimental social science research. The recruitment email (Appendix 7) refers to a card game related to the social science of space exploration.

Three experimenters were present to moderate the game, document the discussions, and record player decisions during gameplay. Participants received a ten-dollar gift card for participation, a special Port of Mars magnet when the group survived, and a special Port of Mars water bottle for the player who earned the most Accomplishment points. Participants did not know the number of rounds that would be played, but knew it would not take longer than two hours. Most of the games were finished after ninety minutes for the nine rounds of the experiment.

From the nineteen groups, eighteen kept the Upkeep level positive for the full nine rounds. This is in line with expectations since we know that communication, even when promises cannot be enforced, lead to a high level of cooperation in public good and common-pool resource dilemmas (Isaac and Walker, 1988; Ostrom et al. 1992; Janssen et al. 2010). The participants did not know what the Events would be but assumed they should be avoided, and therefore most groups tried to stay above the sixty-five threshold (Figure 8), below which they would need to draw an extra Event card per round. This observation is in line with recent work on tipping points (Schill et al. 2015) and

Collective Risk Social Dilemmas (Milinski et al. 2008) that demonstrate how thresholds lead to a higher level of cooperation.

In 54% of the rounds beyond the second, the Upkeep level was ninety or higher, which keeps the number of Events equal to one per round. This shows that the groups aim for high levels of the Upkeep. In fact, most groups agreed to keep the Upkeep high enough to avoid it going below sixty-five and increasing the likelihood of negative Events. The participants did not know the nature of possible Events, but they largely assumed that they would be bad. Only one group purposely dropped below sixty-five just to see what would happen.

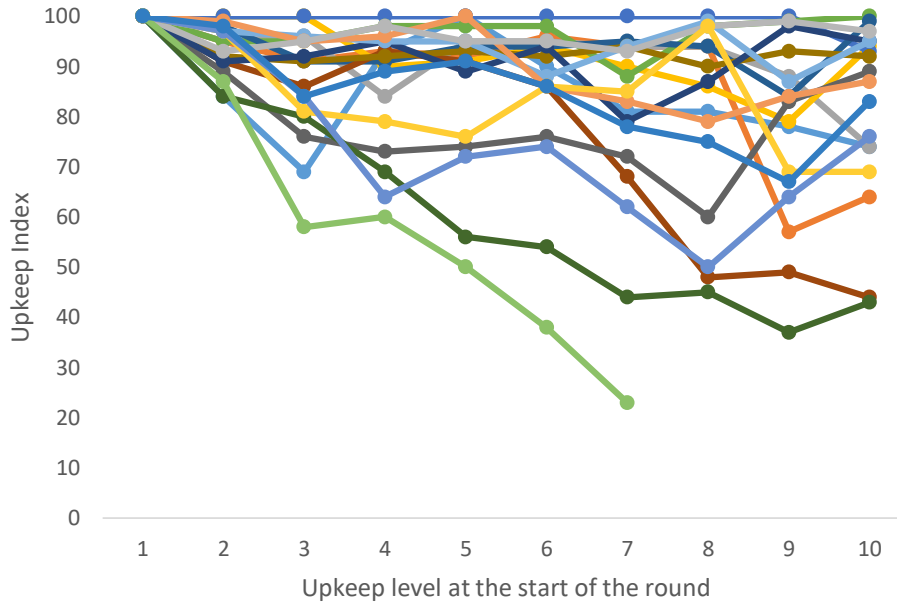


Figure 8: Upkeep level at the start of the round. Round ten could be calculated after decisions made in the final round nine.

When we calculate the cost for event cards for all the groups, we see that there is a strong correlation with the points of the group as a whole collected (Figure 9). The low performing groups typically had a bad start due to costly Events in rounds two or three, or not investing fourteen or more in round one, triggering the requirement to draw two Event cards in round two.

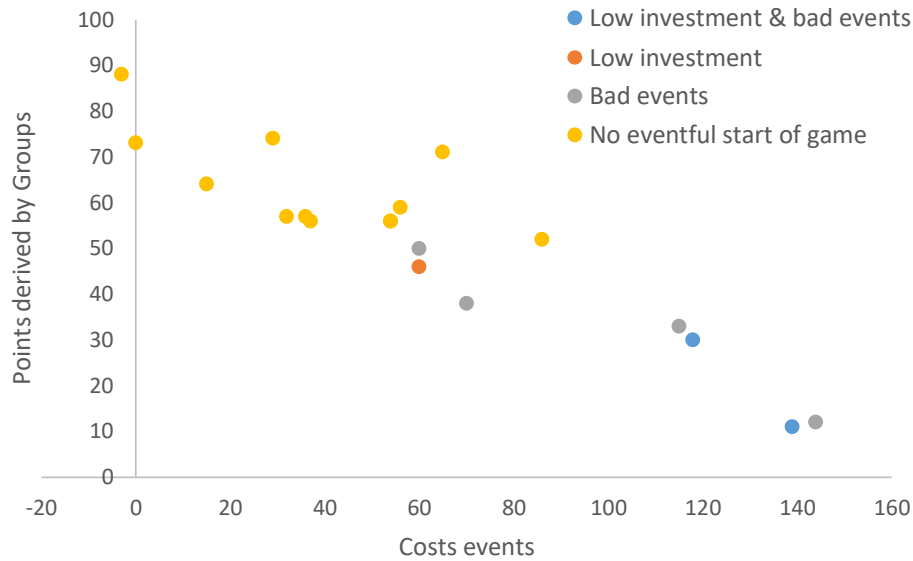


Figure 9: Relation between points groups earned over nine rounds and the costs of the event cards.

A linear regression model shows the group performance measured in points over nine rounds. We included only the eighteen groups who survived the game. We tested the impact of Event cards, the number of points derived divided by the number of Time Blocks available (efficiency), the number of trade made, the efficiency of trade (percentage trades made with Influence participants specialize in), and the majority of the group pointing to the same person as the leader (Appendix 5).

We found that the higher the cost of Event cards drawn by a group, the lower the total number of points they earned, as shown in Figure 9. We also found that the more points per Time Block a group derived (after accounting for Event cards), the higher the number of total points a group earned. Furthermore, we found that the number of trade events correlated with a better group performance. What's more, a lower trade efficiency also correlated with a better group performance. This seems counter-intuitive, but could be explained by the lower variance of trade-efficiency levels within the group, and because a lower trade-efficiency could indicate that participants are helping each other out when they need Influence to buy Accomplishment cards, even if they do not use the cards they specialize in. Finally, the presence of a clear leader has a positive effect on the performance of the group.

Table 1: Results of linear regression for the 18 groups who survived the 9 rounds of the game. *** refers to $p < 0.01$; ** refers to $p < 0.05$ and * refers to $p < 0.01$

| Variable | Coefficients |
|------------------------|---------------------|
| constant | 63.543 (8.013) *** |
| Cost event cards | -0.379 (0.024) *** |
| Efficiency | 112.771 (10.413)*** |
| Trade efficiency | -40.364 (8.529)*** |
| Number of trade events | 0.177 (0.065) ** |
| Clear leader | 2.483 (1.289) * |
| | |
| n | 18 |
| R ² | 0.985 |

For the individual-level data, we used a logistic equation to estimate which factors impact the probability that an individual will win the game. Winning the game is achieved when a player received the most points. In some games, two players ended with the same number of points after which the winner was defined by a coin toss. In our statistical analysis, however, both players are identified as winning the game.

We found the use of the ‘dirty’ card to be the most distinctive predictor of a person winning the game. Interestingly, a high percentage of winners were identified by players as the leader of the group. This could be because leaders had a better understanding of the game and superior strategic insight. A more cynical explanation is that these players used their leadership skills to manipulate others into making decisions that increased their chances of winning.

Players who won the game made comparatively smaller contributions to Upkeep than other group members. Lower investment in Upkeep allowed these players to devote more Time Blocks to gaining Influence, and thus increased their ability to purchase Accomplishment cards to rack up points. The “Out of Commission” Event card did not impact the chances of a person winning the game, nor did trading strategies.

Table 2: Results of an ordered logistic regression for the ninety individuals in the eighteen groups who survived the nine rounds of gameplay. *** refers to $p < 0.01$; ** refers to $p < 0.05$ and * refers to $p < 0.01$

| Variable | Estimations |
|---------------------------------------|-------------------|
| Dirty card | 0.316 (0.108) *** |
| Share leader | 2.616 (1.008) *** |
| Relative Upkeep investment | -5.838 (3.001) * |
| “Out of Commission” Event card | -1.098 (0.732) |
| Number of trades | -0.061 (0.094) |
| Trade efficiency | 2.514 (1.843) |
| | |
| Number of observations | 90 |
| Likelihood Ratio (LR) Chi-Square test | 21.89 |

We used a survey (Appendix 6) to derive information on the cultural orientations of participants (Kahan et al. 2007). The survey of Kahan et al. is based on a cultural theory developed by Douglas and Wildavsky (1982) and Thompson et al. (1990). This theory assumes that people have different views of how the world works and how to manage risk. It identifies four types of world views defined by two dimensions (Figure 10). The “group” dimension represents the degree to which the individual’s life is sustained by group membership. The “grid” dimension measures the significance of social differentiation within a worldview. Persons with a high grid orientation expect resources, opportunities, respect and the like to be distributed on the basis of explicit public social classifications, whereas low grid orientations value a more egalitarian distribution.

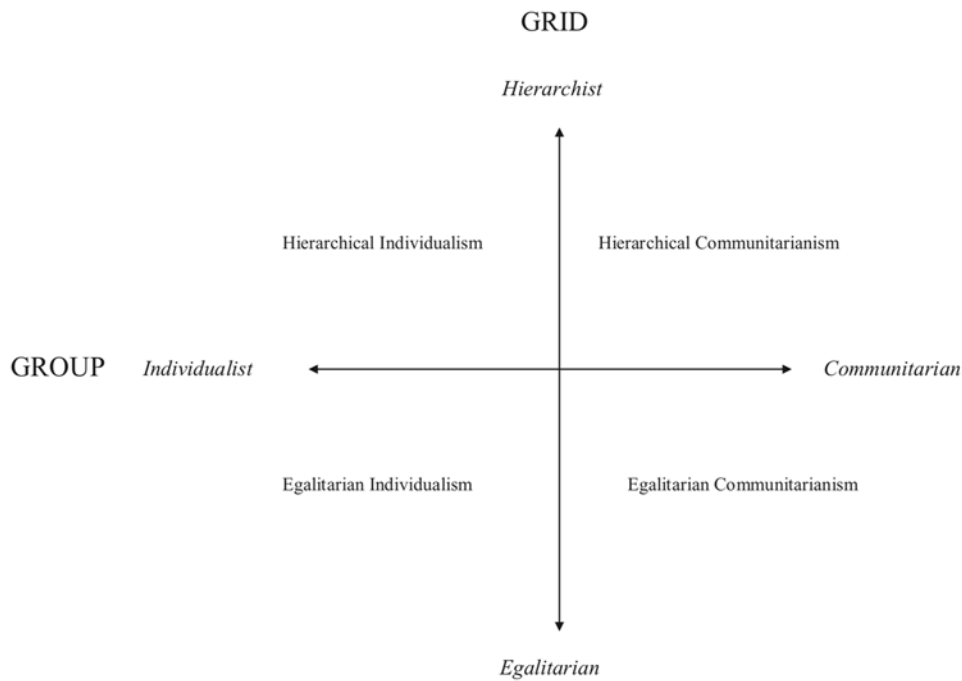


Figure 10: Cultural orientations according to Kahan et al. 2007.

Based on the relative scores on the survey, we classified each participant in one of four categories. Some individuals could not be classified since their scores were on the border of two categories. We identified eleven participants as individualist and hierarchical, eight participants as communitarian and egalitarian, twenty-six participants as individualist and egalitarian, and thirty-three participants as communitarian and hierarchical.

We recorded when a dirty card was available for players to purchase, and whether or not they played it when it was available. Thus, we were able to calculate, for each category of player, the probability they would use an available dirty card. We found that those identified as more communitarian/egalitarian were least likely to use the dirty card, while those identified as individualist/hierarchical were nearly twice as likely to use it. This is consistent with the observation that using a dirty card can be considered a selfish act, hurting the collective interest. Similarly, we identified the probability of a player winning. This was highest among those who are individualists and egalitarian. The

number of groups was too small to identify compositions of cultural views that would perform better as groups.

Table 3: Using cultural views to identify types of behavior.

| Cultural type | Number | % using a dirty card when available | Probability player wins |
|------------------------------|--------|-------------------------------------|-------------------------|
| Individualist / hierarchical | 11 | 14.3% | 9% |
| Communitarian / egalitarian | 8 | 8% | 25% |
| Individualist / egalitarian | 26 | 14% | 31% |
| Communitarian / hierarchical | 33 | 11.5% | 18% |

We also analyzed the communication information we collected but did not find a quantitative measure that explained the performance of the groups. We typically saw more discussion of game rules in the first few rounds. Each round, most groups discussed how much to invest and planned trades. There were differences in the amount and type of communication. Some groups were very inclusive, checked in on each other, and confirmed agreements. Others had minimal exchanges and rarely tried to confirm agreements. Group communication was also impacted by Events, and it is, therefore, no surprise that there is no obvious causal impact of the type of communication with the data we have collected.

Conclusions

In this study, we explored how groups of individuals perform in a system with shared resources in conditions of high uncertainty and high risk. Our sample is too small to make firm conclusions, but the pilot study demonstrates that informal communication allows groups to successfully avoid resource overharvesting. We also find that the existence of thresholds makes the participants more risk-averse.

Our study also displays a new way of including uncertainty in commons dilemma experiments. Traditionally probabilities are provided for which certain specified events can happen. This follows the tradition of calculating the expected returns needed within the rational choice framework. In Port of Mars, we included unknown unknowns. Participants did not know what kind of events could happen in the game and made assumptions on what those might be.

We are now in the process of creating a digital version of Port of Mars that will allow us to run experiments with greater efficiency, increase our sample size, and collect player discussion data accurately to derive objective measures of communication.

In the coming years, our governance of shared resources will increasingly experience new challenges due to humankind's disruption of the biosphere. We need new approaches to collaboration with shared resources in extreme environments. The Port of Mars experiment is a useful means to study such situations, and a possible educational tool for students to experience collective action challenges under high uncertainty.

Acknowledgments

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Data and code availability statement

The code of the NetLogo model that is used in this study is openly available at <https://www.comses.net/codebase-release/90dac191-572a-48d3-ab80-2cbc2f566484/>.

The data that are used in the statistical analysis is openly available at https://osf.io/mqyux/?view_only=db301a2f5e0548319fe8d2aad64cfdff

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Appendix 1: List of event cards

| Name | effect | Costs |
|---------------------------|--|--|
| Changing tides | Each player discards all their Accomplishment cards and draws 1 new Accomplishment card. (They still draw up to a total of three cards at the end of this round.) | |
| Personal gain | Each player secretly chooses Yes or No. Then, simultaneously, players reveal their choice. Players who chose yes gain 6 extra Time Blocks this round, but destroy 6 Upkeep. | 0 |
| Breakdown of trust | Each player chooses up to 2 Influence cards they own, then discards the rest. | |
| Bonding through adversity | Each player gains one Influence of their choice. | -2 * 5 |
| Compulsive Philanthropy | Players must vote for one player to put all their Time Blocks into Upkeep this round. | 0 |
| Hero or Pariah | "CHOOSE ONE: <ul style="list-style-type: none"> • Players must vote for 1 player to lose all Influence • Players must vote for 1 player to gain 4 of their specialty Influence" | -2 * 4 (assuming players choose the 4 extra cards) |
| Audit | For the next round, players play with dividers down. (Players can see how each other player allocates their time.) | 0 |
| Efforts wasted | Each player must discard an Accomplishment they purchased. | |
| Markets closed | Players may not trade Influences this round. | 0 |
| Life as usual | No special effect. (12 cards) | 0 |
| Stymied | Players may not earn their specialty Influence this round. (Culture for Curator, Business for Entrepreneur, Government for Politician, Science for Researcher, Legacy for Pioneer) | 1 for each influence card |
| Time wasted | Each player has 5 fewer Time Blocks to spend this round. | 25 |
| Murphy's Law | Reveal 2 more events. They're both in effect. | 0 |
| Sandstorm | For the next 3 rounds, destroy an additional 10 Upkeep at the start of the round. | 30 |
| Crop Failure | Destroy 20 Upkeep. | 20 |
| Hull Breach | Destroy 7 Upkeep. | 7 |
| Solar Flare | Destroy 5 Upkeep. Skip the discussion and trading phases this turn. (Players may not discuss how they allocate their time and may not trade Influences.) | 5 |

| | | |
|----------------------|--|------------------|
| Interdisciplinary | For this round, each player can spend 3 Time Blocks to earn an Influence in either of the 2 Influences they normally can't create. | 0 |
| Out of Commission | The Politician receives only 3 Time Blocks this round. | 7 |
| Out of Commission | The Curator receives only 3 Time Blocks this round. | 7 |
| Out of Commission | The Pioneer receives only 3 Time Blocks this round. | 7 |
| Out of Commission | The Entrepreneur receives only 3 Time Blocks this round. | 7 |
| Out of Commission | The Researcher receives only 3 Time Blocks this round. | 7 |
| Difficult Conditions | Upkeep costs twice as many Time Blocks, as usual, this round. | 1 per time block |

Appendix 2: List of accomplishment cards

For each accomplishment card we list which of the influence cards (Culture, Finance, Government, Legacy, Science), and how many of each, are needed to buy an accomplishment card, and how many points the player earns when (s)he buys the card, or how much UpKeep the group will lose if a player buys the card..

Researcher

| Accomplishment | C | F | G | L | S | UpK | Points |
|---------------------|---|---|---|---|---|-----|--------|
| Interdisciplinary | 1 | 1 | 1 | 1 | 2 | | 5 |
| Mars Helicopter | 1 | 1 | | | 2 | | 3 |
| Fully Funded | 2 | 2 | | | | | 4 |
| Radiation Shielding | | 4 | | | 1 | | 4 |
| Marsball Suit | 4 | | | | 1 | | 4 |
| Telescope | | | 1 | 1 | 2 | | 2 |
| Terraforming | 2 | | 2 | | | | 2 |
| Land Use Study | | 2 | 2 | | | | 2 |
| Mars Mobile Game | 2 | | | 2 | | | 2 |
| New Food Flavorer | | 2 | | 2 | | | 2 |
| Grant Funk | | | | | | 6 | 3 |
| Mutant Crops | | | | | | 13 | 6 |
| New Facilities | | 1 | | | 3 | | 3 |
| Extended Fuel Cells | 1 | | | | 3 | | 3 |

Pioneer

| Accomplishment | C | F | G | L | S | UpK | Points |
|------------------------|---|---|---|---|---|-----|--------|
| Jack of All Trades | 1 | 1 | 1 | 2 | 1 | | 5 |
| Name Branding | | 1 | 1 | 2 | | | 3 |
| First Martian Business | | 2 | 2 | | | | 4 |
| Political Instigator | | | 4 | 1 | | | 4 |
| Space Influencer | | 4 | | 1 | | | 4 |
| Drone Race Champ | | 1 | | 2 | 1 | | 2 |
| First Marsball Star | 2 | 2 | | | | | 2 |
| Political Memoir | 2 | | 2 | | | | 2 |
| Mining Rights | | 2 | | | 2 | | 2 |
| Mars Public Parks | | | 2 | | 2 | | 2 |
| AWOL | | | | | | 6 | 3 |
| (In)Famous | | | | | | 13 | 6 |
| Explorer's Permit | | | 1 | 3 | | | 3 |
| Luxury Quarters | | 1 | | 3 | | | 3 |

Entrepreneur

| Accomplishment | C | F | G | L | S | UpK | Points |
|----------------------|---|---|---|---|---|-----|--------|
| Diversified Investor | 1 | 2 | 1 | 1 | 1 | | 5 |
| Equipment Contract | | 2 | | 1 | 1 | | 3 |
| Dividends | | | | 2 | 2 | | 4 |
| Rocket Revolution | | 1 | | 4 | | | 4 |
| Habitat 2.0 | | 1 | | | 4 | | 4 |
| Terra Water Craze | 1 | 2 | 1 | | | | 2 |
| Further Automation | | | 2 | | 2 | | 2 |
| Exclusive Contract | | | 2 | 2 | | | 2 |
| Holodeck | 2 | | | | 2 | | 2 |
| Marsball Team Owner | 2 | | | 2 | | | 2 |
| Cutting Corners | | | | | | 6 | 3 |
| Insider Trading | | | | | | 13 | 6 |
| Future Securities | | 3 | | 1 | | | 3 |
| Patent Investment | | 3 | | | 1 | | 3 |

Politician

| Accomplishment | C | F | G | L | S | UpK | Points |
|---------------------------|---|---|---|---|---|-----|--------|
| Know Your Constituents | 1 | 1 | 2 | 1 | 1 | | 5 |
| Favored Candidate | 1 | | 2 | 1 | | | 3 |
| Cultural Legacy | 2 | | | 2 | | | 4 |
| First Port of Mars Leader | | | 1 | 4 | | | 4 |
| Celebrity Martian Recruit | 4 | | 1 | | | | 4 |
| Policy Work | | 1 | 2 | | 1 | | 2 |
| Political Adds | 2 | 2 | | | | | 2 |
| Coining Currency | | 2 | | 2 | | | 2 |
| Mars Tourism | 2 | | | | 2 | | 2 |
| Expansion | | | | 2 | 2 | | 2 |
| Short-Term Gains | | | | | | 6 | 3 |
| Bribes | | | | | | 13 | 6 |
| Polling Well | | | 3 | 1 | | | 3 |
| Charming | 1 | | 3 | | | | 3 |

Curator

| Accomplishment | C | F | G | L | S | UpK | Points |
|----------------------------|---|---|---|---|---|-----|--------|
| A Little Bit of Everything | 2 | 1 | 1 | 1 | 1 | | 5 |
| Marsball! | 2 | | | | 1 | | 3 |
| SNN | | | 2 | | 2 | | 4 |
| Make Science Cool | 1 | | | | 4 | | 4 |
| Politics Podcast | 1 | | 4 | | | | 4 |
| First Marsball League | 2 | 1 | | 1 | | | 2 |
| Weekly Report | | | 2 | 2 | | | 2 |
| Rover Touring Company | | | | 2 | 2 | | 2 |
| Ministry of Culture | | 2 | 2 | | | | 2 |
| Robot Brawls! | | 2 | | | 2 | | 2 |
| Genius Takes Time | | | | | | 6 | 3 |
| Ambitious Sculpture | | | | | | 13 | 6 |
| The Drone Show | 3 | | | | 1 | | 3 |
| Official Sport | 3 | | 1 | | | | 3 |

Appendix 3: PORT OF MARS Information sheet

THE STORY

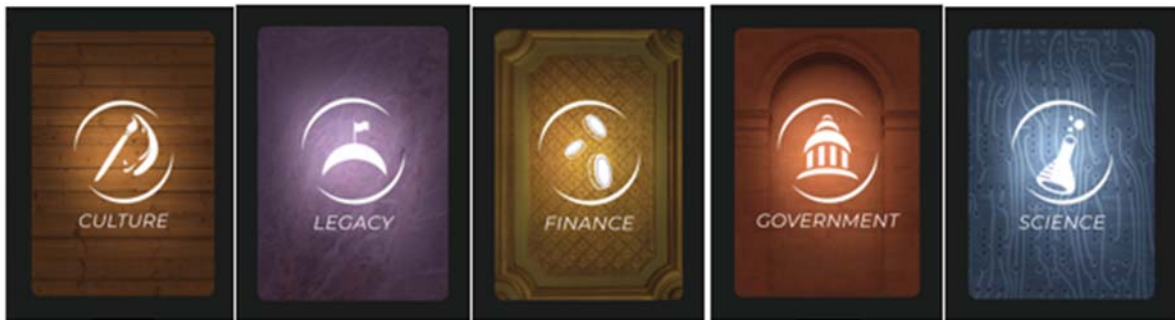
You are 5 residents at **Port of Mars**, the first long term habitat on the planet. Your mission is to *stay alive* and *achieve the accomplishments* you came to the planet to do.

OBJECTIVES

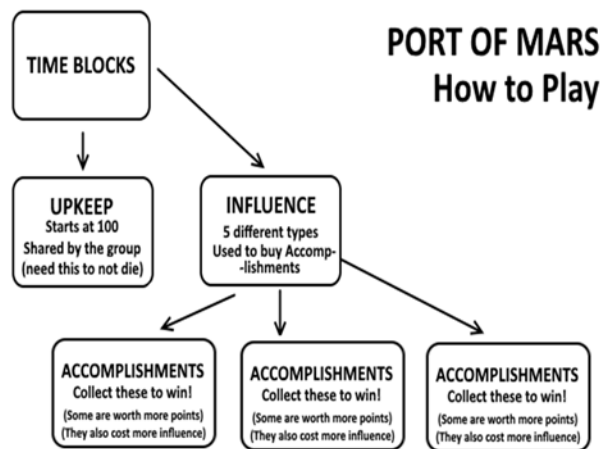
1. Keep **Upkeep** from reaching zero! (If that happens, the habitat collapses, everyone dies, and the game is over.)
2. Earn victory points by achieving **Accomplishments**! Be the player with the most points at the end of the game to win.

Five roles: **Curator, Pioneer, Researcher, Politician, Entrepreneur**

Influence cards: **Culture, Legacy, Science, Government, Finance**



GAMEPLAY: The game will progress in *rounds*. Each round, you will receive **Time Blocks**, which you can spend to earn **Upkeep** or **Influence**. **Upkeep** is needed to keep everyone alive. **Influence** is what you use to buy **Accomplishments**, which is how you win the game.



Round Flow

1. Upkeep

- The game starts with **Upkeep** at 100. This represents the habitat at peak condition and maintenance.
- However, at the start of every round, the community loses 25 **Upkeep**. Conditions on Mars are tough!

2. Event!

- Reveal an **Event card**. Mars is unpredictable; many different events can happen.
- If at the start of a round, **Upkeep** is *lower than 65*, reveal *two* events instead of one. If at the start of a round, **Upkeep** is *lower than 35*, reveal *three* events.

3. Reveal New Accomplishment cards.

- Place *up to three Accomplishment Cards* from your deck face up in front of you. (You should always have **3 Accomplishment Cards** in front of you.)
- **Accomplishment Cards** has several components:



4. Time Blocks

- You get 10 **Time Blocks** (unless something says otherwise) to spend each round.
- You can spend **Time Blocks** on **Upkeep** or on **Influence**.
- One **Upkeep** costs 1 time block.
- Different types of **Influence** costs different amounts of **Time Blocks**, as determined by your **role**.

5. Discussion

- Chat and strategize among the group. You have 5 minutes to discuss and plan.

6. Lock in Time.

- Decide how you will spend your **Time Blocks** on Upkeep and Influence.
- NOTE: Any unspent time in a round doesn't carry over to the next round.

7. Trading

- If you wish, you may now trade any influence you earned with the other players.

8. Purchase Accomplishments

- At this point, if you have the right **Influence** to buy any of your **Accomplishment cards**, you can choose to do so. When you do, read the title of the card, how many points it's worth, and the flavor text out loud. Once you do so, those points will be added to your total, and that card will be removed from the game.

9. End of Round

- The facilitator will reveal how much **Upkeep** the group has produced this round and add it to the total.
- Players may choose to *keep* or *discard* any number of their unpurchased **Accomplishment cards**. Discarded **Accomplishment cards** go to the bottom of the deck. (Remember, next round you'll reveal new **Accomplishment cards** so you always have 3 to potentially purchase.)

The game will continue for an unspecified number of rounds. At the end, whoever has the most points wins!

Appendix 4: Script

Welcome, I am X, a ... here at ASU and I will be assisted today by to do a card game today. Before we go to the instructions I ask you to turn off any mobile phones and other mobile devices that can disturb the experiment. If you have a question, raise your hand, and I will address your question.

The duration of the experiment is a maximum of 2 hours. You earned a 10 dollar Amazon gift card by showing up here on time. Dependent on the decisions you make you can earn additional goods as explained in the instructions.

The game we are gonna play is called Port of Mars. You are each a member of Generation Zero in the first long-term human community of Mars. Your goal is to keep the community alive while earning individual points by achieving **Accomplishments** that makes Mars history.

Each of you has a special role in Generation Zero. We have five roles, namely Curator, Pioneer, Researcher, Politician, and Entrepreneur. Those roles invest time to get influence cards for Culture, Legacy, Science, Government, and Finance, which are used to earn points.

The basic gist of the game is the following. Each round you have time to spend, say 10 hours a day, and you have to choose how much to invest in the community and how much in your personal interests. The upkeep level of the community needs to stay positive otherwise it is game over for all of you. You play an unknown number of rounds, and if you keep the community alive, you all get a special Port of Mars magnet. The person will get the most points during the game will also get a special Port of Mars water bottle, and of course a place in the Port of Mars Hall of fame.

You have instructions in front of you and I will ask you to read them in a minute. But first I want to make sure you know what are the time blocks (show them) that you invest in activities to earn influence cards. With the right set of influence cards you can earn accomplishment cards, and you will have each round 3 accomplishment cards in front of you.

When you choose to invest your time blocks you have 6 options as you see on your play sheet in front of you. In the left top corner, you place the number of time blocks you want to invest in upkeep. The rest is to obtain influence cards. Each player has one influence topic they are good at earning (costs 2 time-blocks to earn 1 influence card), two influence topics they can earn (costs 3 time-blocks to earn 1 influence card), and two influence topics they can't earn at all. You see this at the right part of your play sheet. To get influence cards for those topics, you will have to trade with other players.

One special card that needs explanation is an accomplishment card with Upkeep symbol. [how example] The cost, in that case, is a reduction of upkeep for the group, not that you use upkeep time investment to collect the points.

So read the instructions carefully, and then we can address some of the questions you have.

[participants read instructions]

Are there any questions?

[Address questions]

We know that not everything might be clear at the start of round one. That is also the reason, we do not use an event card in round 1. So let's start round 1 with an upkeep index of 100. The first thing we do is to reduce it with 25 units, leading to 75 units left.

Now reveal 3 accomplishment cards by taking them from your stack.

You all have 10 time-blocks to invest.

Now you have 5 minutes to discuss with the other players on what you plan to do which include potential trade arrangements. You can discuss whatever you want as long as you don't use any offensive language or make promises about side payments after the game.

Now you have to finalize your time allocation.

The observer will give the influence cards, and the data recorder will record your time investments.

Now you have time to trade influence cards.

Finally, you can spend your influence to earn points to buy accomplishment cards. You may also discard accomplishment cards now and the next round you can fill it up to 3 accomplishment cards.

.. [play the rest of the game]

This was the last round, but not the end of the experiment. You are asked to fill in carefully a brief survey and do brief interviews. When some of you get a brief interview the others will fill out the survey.

Appendix 5: Interview questions

Session. Date:

Time:

Interview questions:

1. What was your role in the game?
2. What was your goal at the start of the game?
3. Did your goal change during the experiment?
4. What do you think about your achievements during the game?
5. What do you think about the achievement of the group during the game?
6. How well did your group work together?
7. What were the key events in the group during the game?
8. If you have to select one person in the group that acted as a leader, who was this person (role in the game)
9. Why do you say this person acted as a leader?

Appendix 6: Survey

Session. **Day:** **Time:**

Role in the game:

Please respond to the following questions. All information that you provide will be kept in strict confidence and all participants' answers will be combined and presented in the form of summary statistics, such as tables and graphs.

Please answer all questions. Please select ONE checkbox for each question, where appropriate.

1. How old are you? _____ years

2. What is your gender?

Female

Male

Other

Prefer not to answer

3. What is your major of study? _____

4. Which year of study are you?

Freshman

Sophomore

Junior

Senior

Graduate Student

5. For each of the statements below select via an x in the appropriate column, whether you strongly agree, agree, disagree or strongly disagree.

| Statement | Strongly agree | agree | disagree | Strongly disagree |
|--|----------------|-------|----------|-------------------|
| It seems like the criminals and welfare cheats get all the breaks, while the average citizen picks up the tab. | | | | |
| People who are successful in business have a right to enjoy their wealth as they see fit. | | | | |
| Private profit is the main motive for hard work. | | | | |
| If the government spent less time trying to fix everyone's problems, we'd all be a lot better off. | | | | |
| We have gone too far in pushing equal rights in this country. | | | | |

| Statement | Strongly agree | agree | disagree | Strongly disagree |
|--|----------------|-------|----------|-------------------|
| It's not the government's business to try to protect people from themselves. | | | | |
| It's old-fashioned and wrong to think that one culture's set of values is better than any other culture's way of seeing the world. | | | | |
| Society works best when it lets individuals take responsibility for their own lives without telling them what to do. | | | | |
| Society as a whole has become too soft and feminine. | | | | |
| Government regulations are almost always a waste of everyone's time and money. | | | | |
| We live in a sexist society that is fundamentally set up to discriminate against women. | | | | |
| Our government tries to do too many things for too many people. We should just let people take care of themselves. | | | | |
| Nowadays it seems like there is just as much discrimination against whites as there is against blacks. | | | | |
| Sometimes government needs to make laws that keep people from hurting themselves. | | | | |
| A gay or lesbian couple should have just as much right to marry as any other couple. | | | | |
| The government interferes far too much in our everyday lives. | | | | |
| Government should put limits on the choices individuals can make so they don't get in the way of what's good for society. | | | | |
| It seems like blacks, women, homosexuals and other groups don't want equal rights, they want special rights just for them. | | | | |

| Statement | Strongly agree | agree | disagree | Strongly disagree |
|---|----------------|-------|----------|-------------------|
| It's society's responsibility to make sure everyone's basic needs are met. | | | | |
| We need to dramatically reduce inequalities between the rich and the poor, whites and people of color, and men and women. | | | | |
| The government should do more to advance society's goals, even if that means limiting the freedom and choices of individuals. | | | | |
| A lot of problems in our society today come from the decline in the traditional family, where the man works and the woman stays home. | | | | |
| Free markets--not government programs--are the best way to supply people with the things they need. | | | | |
| People should be able to rely on the government for help when they need it. | | | | |
| Parents should encourage young boys to be more sensitive and less "rough and tough." | | | | |
| Too many people today expect society to do things for them that they should be doing for themselves. | | | | |
| The women's rights movement has gone too far. | | | | |
| Our society would be better off if the distribution of wealth was more equal. | | | | |
| It's a mistake to ask society to help every person in need. | | | | |
| Discrimination against minorities is still a very serious problem in our society. | | | | |
| The government should stop telling people how to live their lives. | | | | |

Appendix 7: Recruitment Notice:

We are offering an opportunity for you to earn **\$10** and have the opportunity to earn space gadgets for 2 hours of your time by participating in a study about the social science of space travel. All participants will receive a minimum of \$10 for showing up on time and additional gadgets can be earned depending on decisions made during the experiment. All participation is voluntary.

We invite alternates to sign up for the experiment since not all people who sign up show up on time. If you are signed up as an alternate and you arrive on time, but we have sufficient participants, you will receive **\$5** and you can be invited for another session.

Exact earnings will be determined at the time of study based on the decisions you make in a group.

The study will take place on the main Tempe Campus in room MU 208 Chrysocolla Room of the Memorial Union.

Please arrive on time. If you do not arrive on time you will not be able to participate.

To sign up, please visit: [links to specific sessions]

Send questions to **marco.janssen@asu.edu**.