The Seed Colony Model: An Approach for Colonizing Space

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Abstract -- **As humans reach out to the stars in a variety of exploration missions beyond Earth, eventually mission architecture will include constructing a permanent habitat and establishing a colony. Given the complexity of colonizing a planet, such as Mars, a great deal of research, simulation, and planning is necessary to identify the optimal model for colonization in order to guide future mission architectures. One such model, which has received a significant amount of publicity, is that of the "Mars One" organization and its plan to build a colony one piece at a time by sending up small groups of people every 2 years. Although critique of this or any model can focus on a number of predominantly engineering-focused areas, from propulsion technologies to habitat design, the present paper uses a human factors perspective to evaluate the Mars One approach. This critique also presents a more theoretically sound model, the Seed Colony Model (SCM), and, using existing literature, outlines how this approach has advantages for future colonization missions that highlights the human element.**

Specifically, a variety of potential psychosocial issues for a colonization mission are explored. These include territoriality caused by an individual experiencing ownership of some aspect of their environment, in-group/out-group mentality due to social constructs, conflict escalation, the lack of a "finish line," and self-selection. All issues are examined in the context of a permanent, sustainable colony. Because human space operations have been limited to smaller groups and had the capability to return to Earth in case of medical emergencies, these previous spaceflight missions are not an accurate representation of the social aspects of a Mars colonization mission. To better represent the conditions, the current paper focuses on experiences from Antarctic missions, where larger teams spend a winter-over in that hostile environment with very limited opportunities for re-supply or extraction.

Although colonization missions are in the distant future, this paper aims to develop the theory to support the need for human-centric design considerations for these missions. The SCM, when employed for mission planning, will provide an over-arching system architecture to improve mission success rates. This model is designed around the interactions and complexities of a team, and individual differences in crewmembers, and injects decades of research in the behavioral sciences into the plan to send humans to live on another planet.

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1. INTRODUCTION

In hopes to be an insurance policy from the dangers to our civilization (e.g., asteroid impact, warfare, disease), space colonization has been argued to be the only intelligent way to ensure what humanity has developed over the past few millennia will not be lost [18]. As NASA's long-term objective is to land astronauts on the Mars surface by the 2030s, private companies and national agencies alike have shown interest in the eventual colonization of this Martian environment. However, Mars presents unique challenges, and human space colonization is significantly different than human space activity to date, which involves low-Earth orbit and lunar explorations with small crews for limited periods of time [19].

Despite these significant differences, the rush to settle has been driven by several high-status space advocates and organizations such as the Mars One project [19]. Yet, colonization will require not only an enormous amount of engineering and technological advances to keep the future residents alive (e.g., [6]), but also a deep comprehension of the human component.

Because human behavior is often affected by the actions and emotions of others as well as the impact of the situation itself, it is imperative to understand the negative consequences of space colonization from a psychosocial perspective. Unfortunately, empirical research on the social psychology of permanent colonization is essentially non-existent, and research on extreme environments is typically limited to individuals or small teams. Nevertheless, evidence suggests humanity is not ready for such a leap, but people are still eager to get to Mars. Thus, this paper identifies key psychosocial issues that will occur during the current space colonization plan presented by Mars One as well as propose an alternative design, ensuring that the settlers can surpass these hurdles once technology has been advanced enough for missions to commence.

2. Psychosocial Issues With Mars One Colonization

Focused on creating a permanent settlement in the Martian environment, Mars One has already started choosing individuals for a one-way trip to colonize the planet in the 2020s. Mars One's current model for colonization, perhaps the best publicized, involves a slowly growing colony. This private organization expects to have a series of launches with four individuals each mission, occurring roughly every 2 years. These launches will send individuals on a one-way journey to live out the rest of their lives in the prepared area, resulting in a slowly increasing colony designed to be self-sustaining [9].

In a mission to colonize an extreme environment, an off-nominal event can easily result in loss of equipment, life, or cause a catastrophic mission failure. The Mars One mission has been criticized for a variety of technical reasons that could result in this outcome (e.g., [6]), yet the social difficulties that it will create have not been thoroughly explored. The Mars One plan was analyzed to identify possible psychosocial causes of off-nominal events. The factors in this paper were chosen based on their potential for disaster in a colonization mission, as well as their relationship to anecdotal findings of Antarctic research missions. Following the review of existing literature, this paper identifies five main causes of an unsuccessful Mars One colonization from a psychosocial perspective: territoriality, in-group/out-group, conflict escalation, lack of a "finish line," and self-selection.

Territoriality

When individuals are living or working in an environment, they tend to develop some sense of ownership of various aspects of their surroundings [5]. This psychological ownership, known as territoriality, can be applied to many areas, from the environment (e.g., living quarters, workspaces) to a task or assignment (e.g., being in charge of rover maintenance or getting to choose the music on a certain night each week). When competing needs arise, invoking a threat to this ownership, potential issues can grow. Territoriality has also been introduced as a group construct, where the group will identify a space or task as "theirs" [16]. Territoriality leads to an increase in motivation, especially if the person had some part in creating the territory [2]. Additionally, individuals tend to care for and nurture what they feel ownership of, so this territoriality seems to be based on a psychological need, meaning it needs to be aided instead of removed from colonists.

In reference to the Mars One colonization, these conflicts will arise when a new group arrives to Mars. Those living on the planet will have already developed a routine, after living in the same environment with the same people for many months. The same can be said of the new set of four people to arrive, who will also have months in physical isolation with only themselves. Both groups will develop ownership of certain spaces and tasks, and then be abruptly forced together. Suddenly, common spaces will see an influx of users, forcing those already on-site to adjust ingrained habits. These habits can be as simple as sitting in the same spot every day for a meal, to as dynamic as changing housing arrangements. Tasks will also be a cause of territoriality as the population grows. Because Mars One aims to become self-sustaining, the number of individuals with the same expertise will increase. For example: as the population increases, the need for physicians will increase as well. This goes for most roles in a society – demand is higher as the population grows. Because of this, existing experts in the community may feel threatened by or territorial toward the newcomers.

In-group/Out-group Mentality

As groups form, they also develop a sense of an in-group and out-group mentality. This mentality, which can be as simple as having a perception of belonging to one group, can lead to discrimination that favors the individuals' identified in-group [21]. This discrimination can escalate to much more extreme conflict, where individuals actively work in opposition of their out-group. A classic example of this mentality is explained by Sherif [17], who divided up boys at a summer camp into two groups and tasked them with cohesion-inducing tasks, such as making a team flag. As time went on, these groups displayed this in-group and out-group mentality, showing a clear preference for their own team (in-group) and bullying kids who were on the other team (out-group).

In Mars One, each group of new people could be quickly categorized as an out-group by those already living on Mars, leading to the potential for conflicts between each group. Although new groups can form as time goes on, the territoriality of the group that is already living on Mars increases this in-group and out-group mentality and can have a major impact on developing a sense of community among the whole team.

Although the study explained by Sherif [17] was able to overcome the divisions of the boys by forcing cooperation among the groups and unify them through what could be considered additive survival tasks (i.e., having more people to work on finding the leak meant less work to ensure their well-being),

this will not work for the Mars One colonization mission. Instead, more people will increase the strain on the extremely limited resources. Individuals may feel threatened by additional groups, especially when new groups drastically increase the population size in the early stages.

Unfortunately there also is always the possibility that an individual will be in some way ostracized from the group. For example, during an Antarctic mission that involved a smaller number of people living in the research station, one individual would avoid some of their daily tasks because they did not like any work that involved going outside. This caused conflict and led to that person becoming the sole member of the out-group. Eventually, psychologists had to be contacted, and the individual was moved to a larger research station with more variability in roles [20]. This also has implications for Mars One, since the first few groups may not have a lot of room for variety of personnel beyond the required survival needs.

Conflict Escalation

When groups of individuals are together for a long amount of time and in close proximity, conflicts will often occur. As discussed by Stuster [20], even simple conflicts will often escalade to severe proportions, especially in extreme environments. For example, the aforementioned individual who avoided daily tasks eventually became ostracized because of it, and there have been numerous recorded instances where issues such as personal hygiene become a major conflict over time (e.g., an individual who would put soup in the same cup every day and never washed it [20]).

This conflict escalation will be evident during the Mars One mission. No human relationship is perfect, and so there will be issues that will arise as individuals are trapped in close proximity with each other. Although society on Earth has plenty of ways for people who have conflicts over time to avoid others, from not spending time around the person to social media un-friending and filing for divorce, none of these capabilities will be present on Mars.

Lack of a "Finish Line"

Another common trend found in extreme environment research and anecdotal evidence is known as the third-quarter phenomena, where the third quarter of an expedition involves more frequent characteristics such as emotional outbursts and aggressiveness [22] [3] (See Figure 1). The timeline of this effect is consistent across missions of different lengths as well as present in space-analog missions (e.g., Mars500 mission; [22]). Although these levels tend to go back to about the baseline after the third quarter as the group approaches the "finish line" of their mission, the third-quarter phenomena can have major consequences for the cohesion of a group. This problem is theoretically heightened in the case of Mars One where there is no end-goal, and individuals are faced with living out the rest of their lives on Mars with no possible return to their previous reality. Without the "finish line," the return to baseline seen in other extreme environments may not occur.

Because there are no empirical data to determine the effects of the one-way mission on a group of colonists, an illustration could be drawn from individuals who live out their lives in exile. Alfandary [1] identifies an individual suffering with longitudinal psychological and physical symptoms due to exile years prior to seeking help. Although self-inflicted, the journey to live on Mars with no return can be classified as

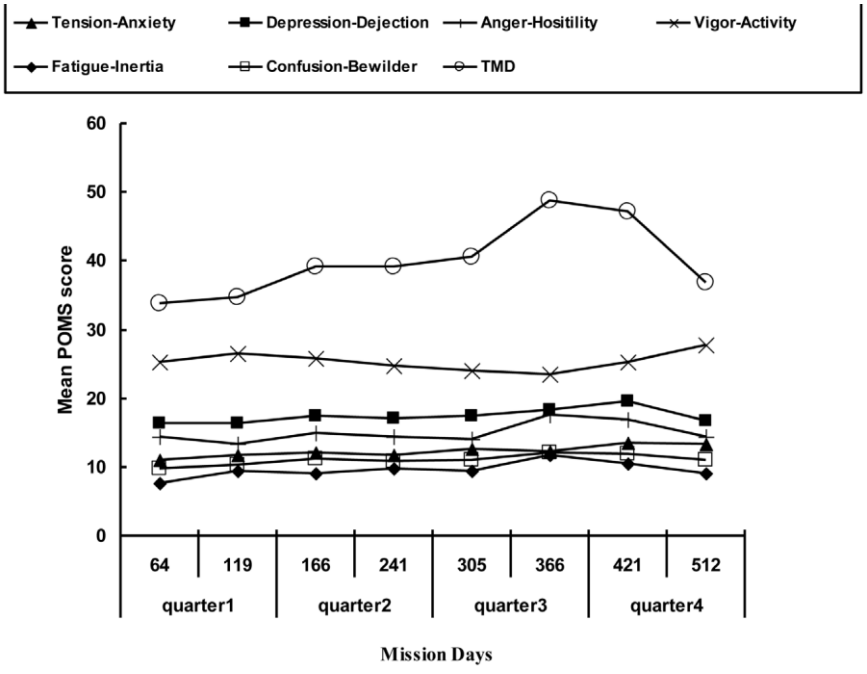

Figure 1: Third quarter spike in Total Mood Disturbance [22]

exile. Alfandary's patient eventually recovered with psychological help, but without it, he may have continued his downward spiral, showing that there is potential for issues in a long-term mission.

Self-Selection Issues

Another interesting aspect of the Mars One program is that their aim is to fund the program using TV exposure [11]. While publicity caters to the historical nature of a small group of four being the hopeful first people to live on Mars as well as one individual getting the equivalent of the historic first step of Neil Armstrong, there may be an issue of participants being those that in some way want to be famous. Maltby [8] found that individual characteristics were determinant of fame-seeking behavior, and there are positive correlations between different sub-items on the Fame Interest scale and the personality factors neuroticism and extraversion.

If participants are not chosen from the general population attracted by Mars One's mission plan, the other specific population that can be logically expected to contribute humans to this mission are the various national groups of astronauts, cosmonauts, taikonauts, and others that make up the corps of trained and dedicated space explorers. These populations provide their own unique composition, with work by Musson, Sandal, and Helmreich [14] finding that compared to the normative values taken from a large number of students, successful astronaut applicants had a significantly higher level of extroversion.

Because extant research has found that performance in an extreme environment is lower for those with higher levels of extraversion and neuroticism [15], the people self-selecting for some level of fame would be problematic for this kind of mission. This means the Mars One mission strategies could result in interest from individuals who may not be the best choice for an isolated and extreme environment. Additionally astronauts themselves, although significantly less neurotic, still demonstrate a higher level of extraversion than a normative population. This suggests that although astronauts can be considered better candidates than fame-seekers, they still may not be the ideal choice for performance in the extreme environment of a place such as Mars.

3. RECOMMENDATION: SEED COLONY MODEL

To address potential catastrophic mission failures of a colonization mission to Mars due to psychosocial issues, the Seed Colony Model (SCM) was conceptualized for the current paper. The term "seed colony" is one that has long been referenced in science fiction literature and is used to refer to a colony that will, like a seed, eventually grow into something much larger. Sometimes, this can refer to a colony of people, whereas for other examples the name implies a double meaning -- a sort of sperm and egg bank sent into space. In case more rapid growth is needed, or no way of supplementing the gene pool exists, the latter definition is a possibility, but for this paper the assumption will be that the colony is made up of fully developed humans. The word "seed" is especially important because a seed has a lot of versatility. It has most of what it needs to start growing internally, as long as some environmental needs are met such as water and soil. In the SCM, this should also be true: the colony spacecraft should transport all of the necessary resources to grow wherever it is planted. This includes personnel, food production, manufacturing, health services, etc. This means that the ideal seed colony will not rely on supply drops or pre-constructed infrastructure to operate, instead bringing the means to construct infrastructure and all required supplies with it.

Although both Mars One colonization and SCM aim to minimize the potential mission risks and create a self-sustaining colony on another planet, the future colonists' journey to Mars will be substantially different. Specifically, the SCM will alleviate the psychosocial issues apparent in the Mars One colonization.

Addressing Territoriality

One of the main differences between the proposal of Mars One and the SCM is that in the latter all equipment and personnel would arrive together. Because the seed colony itself should, like a seed, be planted at a single time, the colonists would have a higher sense of autonomy. For example, if they wanted to, they could potentially change their target zone and set up a colony in a different location. Even though the team would most likely end up in the studied and pre-decided location, it still would give participants more of a feeling of control over their new environment. There would not be the created ownership by one group spending a longer period of time at the base. In addition, if individuals already have all of the components of their future home with them instead of set up previously, they would also be able to better fulfill their psychological need by having more of a hand in actually building their habitat [2]. This further differentiates it from Mars One, which has each group constructing the habitat in preparation for the next group to arrive [9], leading to even more territoriality for those preceding groups.

Addressing In-group/Out-group

No matter how the colony is designed, having large groups will typically result in the formation of sub-groups [4] and too many differences can lead to division. To address this in a colony, the key therefore is not to eliminate sub-groups altogether, but instead to limit the amount of divisions, or "fault lines," of these sub-groups by having them live through the entire process together. For example, the "clubs" at Antarctic research stations with different profession demographics (e.g., naval officers, scientists) often see little to no interaction between these demographics [20]. If that kind of division exists, it is also likely that gaps will exist among colonists who are sent years and years apart. Even technology creates a cultural difference that could occur with a gap of only a few crews from Mars One. By eliminating fault lines

such as length of time on Mars and temporal cultural experiences prior to embarking, a large number of fault lines can be eliminated.

Another advantage of a large group is the ability to have task variability. In the book "The Martian" Mark Watney had to dust off his solar panels frequently to ensure they would give sufficient power, which is an arduous task that would probably not have much job satisfaction to offer. With more people, a task like this could be divided to minimize requirements from each individual, lessening the impact of onerous chores. Additionally, with the individual described previously that was ostracized because of an unwillingness to work outside [20], the solution reached was a transfer to a larger station because with a larger population comes more of an ability for specialization instead of being involved a little in all aspects of station life. Therefore, having the large group live through the entire process together should be considered to help limit sources of conflict.

Addressing Escalation and "Finish Line"

To address escalation and the "finish line," the solution can probably be reduced to something often overlooked, which is having some kind of therapist or counselor on hand to help mediate conflicts and emotional needs. This is especially important because of the time delays that would exist, making it difficult for any sort of intervention from Earth. This time delay, coupled with Mission Control most likely becomming an outgroup to colonists, will mean that intervention from Earth may not help: people sitting at home in comfortable chairs trying to tell those working hard and fighting for survival never results in an effective relationship. The individual that Alfandary [1] wrote about did reach a point of being able to recover from the long-standing issues that stemmed from his exile, but only after counseling. Counseling could also be very effective in mitigating conflict escalation by the use of various trained intervention techniques to stop conflicts early.

Thus, mitigation of escalation and the "finish line" requires there to be at least one counselor. However, a minimum of three people is recommended to be present for each counselor to have one of their own. The presence of these individuals would work much better with the larger size of the SCM, because with only the handful present in the initial colony, dedicating three of them part-time to counseling training ahead of the mission can take away from other areas. Beyond counselors, a larger size means that a lot of other expertise can be included in the initial colony too.

Addressing Self-Selection

The best way to address self-selection from the Mars One strategy is to change the marketing scheme, however, this scheme was decided on because of a need to ensure funding. Mars One does have a psychologist who is evaluating potential participants [10], so personality may have been sufficiently studied to select-out candidates. Crew selection should explore using a measure such as the Fame Interest scale to cover some aspects not already covered by other evaluations. If individuals are considering the mission to seek fame, it is critical to control for them and eliminate them from the program for a smaller colony.

The specific issues concerning self-selection discussed in the present paper may also be mitigated if the group traveling is large enough. For example, extroversion has an association with poor performance in extreme environments [15]; however, those extreme environments studied are also often fairly small populations, which is not the type of environment an extrovert would say they prefer when taking a personality test. In addition, more people may mean more opportunity to get social fulfillment for those who are more extroverted. In Antarctica, for example, the social “clubs” at larger stations provide much more potential for variation, while smaller stations may have social space limited to some sitting and dining. With a larger colony, more diversity in common space would be easier to design in. Although some comforts will still be left out, at the very least more space would be needed for meals – a large space that could be made flexible to allow for social activities.

Other Concerns

The founding of a colony is considered to be the most critical point when a colony is either slated for success or failure. Therefore, it is most beneficial to understand the psychosocial risks at the onset of this journey. However, the psychosocial perspective has been neglected, especially in regards to the oft-questioned Mars One colonization plan. Because survival is on the line and aspects of maintaining it have not become familiar and routine, sending everyone at once would increase the performance as Littlepage [7] found with an increase in team size. Therefore, the SCM should perform better than an initial group of only four, because an increase in performance can be translated into an increase in chance of survival.

Because of a pre-built site, the gradual colonization method can verify functionality of the habitat at each step of the process before adding more people to live in them. The ideal SCM, however, would require those systems to work upon initial installation. If no pre-built infrastructure is used in order to support crew autonomy, construction of the initial habitat would need to be fairly simple, so that work can be quickly completed while colonists are living in their landing craft. This would minimize time spent in a more compact habitat. On the technical and financial sides, having the crew build their own habitat would have significant advantage over designing autonomous or semi-autonomous robots for assembling facilities.

One important question is the initial size of the colony. Research by Moore [12] looked into growth of groups, and can assist with some perspective. Moore found that the most viable method for colonization is one known as the string of pearls, which on Earth can be illustrated as colonizing along

a river. Each new colony is close enough to the previous one for contact, but is itself surrounded by new territory other than down the river. To achieve populations that would maintain a steady number, 100 people per colony were used in simulation, so when planning for a SCM mission, at least 100 people should be sent for each new colony, otherwise there is an increased risk of the colony dying out. This translates into approximately 50 years of 4-person Mars One missions, which means that by the time 100 people have been sent, there is a very real possibility that earlier settlers will have died of age-related issues.

4. Discussion

The various social issues reviewed in this paper are the most noteworthy ones based on a review of the Mars One strategy, and provide a good starting point to make sure that the needs of participants are never left out. In essence, the argument of this paper is to make sure colony missions are larger and at once, instead of small and gradual groups. This method of colonization should lead to a much more successful mission by mitigating territoriality, harmful in-group/out-group mentality, conflict escalation, the unknown of no "finish line," and issues caused by personalities prone to self-selection. This is not to say that only one colony should be sent to Mars, only that each launch group should be given their own new home and have the ability to sustain their population.

It is noteworthy that other than a few aspects of personality – that may be overcome by the SCM's size – this paper does not address individual variations such as culture, ethnicity, religion, gender, and sexuality. This is purposeful, because a colonization mission will likely be a collaboration between multiple different space agencies with a variety of people involved. This means that a colony will be multi-national and multi-gendered. These personal differences may result in a basis for the inevitable sub-groups, but because all groups would set out as one single unit working to survive together, the potential for conflict between them will be minimized. This leaves the sub-groups as more of a self-imposed social construct instead of a construct imposed by the nature of the mission.

Another important take-away to consider is that because of the unique nature of a colonization mission, a specific pool of candidates should be created that does not automatically accept individuals accepted by astronaut, cosmonaut, and taikonaut programs. Although this paper only touches on one difference between astronauts and ideal candidates for longer-term extreme environment missions, there are potentially many others. Research should be done to explore these potential differences and develop a specialized selection selection process before a colonization mission is finalized.

5. The New SpaceX Plan

Elon Musk [13], an entrepreneur and founder of SpaceX has recently discussed his goals for an eventual Mars colony. The presentation did not go into depth into the human element, but some recommendations to the mission architecture can be made by applying the SCM.

One major point in the SpaceX plan is to drastically increase the number of people able to colonize Mars. This massive number of people should help to mitigate the mentioned self-selection issues, and in the long run the population should normalize to where specialty populations, such as discussed astronauts, will no longer be a concern. However, similar to the Mars One plan, this colony will be effected by the same time frame of when launches occur, so selection should still identify a colony-suitable population for the first "Mars colonial fleet" that Musk [13] described.

The larger population, as well as ships being planned to return to Earth, means that conflict escalation and the "finish line" issues may also be eliminated. This is because individuals will be able to change social groups if needed, or even return to Earth. With the larger population, the suggestion still stands, however, to include several individuals trained as counselors to ensure conflicts and mental illness can be dealt with effectively.

In terms of actually colonizing the planet, the string of pearls method of colonization should be adhered to, where each new "Mars colonial fleet" establishes its own, new colony site roughly along a line or geological feature. This will help with issues created from territoriality and in-group/out-group mentality because each fleet group will be moving into their own space. The best case would be if each fleet includes all necessary structural components, and so can nurture their need for territoriality by allowing them to select their final landing site – perhaps from a list of pre-selected areas – and have more of a hand in actually constructing their new home.

The million-person number Musk [13] used as his goal for the colony is over-kill in terms of a sustainable colony based on Moore's [12] work. However, a larger number in this kind of situation is definitely not bad. Though based on the SCM, with the right technology present, even a single "Mars colonial fleet" should be sufficient to create a sustained population – assuming that care is given to ensure necessary skill-sets and professions are present, processes are automated, and parts are standardized.

6. Conclusion

Future research needs to be conducted to explore the viability and necessity of the SCM. A study that would be particularly interesting would be to use participants living in an analogue for an extended time and have a new group sent in to join them mid-mission. There is also a lot of room for research on complex, aggregate teams in extreme environments, such as the group from a SCM mission, data that can then be compared to existing small team data to see if any kind of differences occur. Researchers should also work to develop interventions specifically for extreme environment issues, and

with them develop training programs for colonists to try to reach an optimum number of at least somewhat trained counselors.

This paper was written because mankind is approaching a point at which our population may overcome the capacity of Earth to sustain us. As we near that time, more thought must be given to ensure mankind's permanent spread beyond Earth, to places such as the Moon, Mars, asteroid belts, and eventually out to live under the light of other stars. Without a doubt we will eventually reach this stage, but before we do, we need to understand how to best go about such a mission. The Seed Colony Model presents an alternative strategy to commonly publicized colonization approaches, in order to better meet the needs of those individuals who are a part of a mission to live permanently off of Earth.

REFERENCES

[1] Alfandary, R. (2015). An exile in the room: A clinical illustration and a literary footnote. Psychoanalytic Social Work, 22(1), 23-38. doi:http://dx.doi.org.ezproxy.libproxy.db.erau.edu/10.1080/15228878.2013.846225

[2] Avey, J. B., Avolio, B. J., Crossley, C. R., Luthans, F. (2009). Psychological ownership: Theoretical extensions, measurement, and relation to work outcomes. *Journal of Organizational Behavior*, *30*, 173–191.

[3] Bechtel, R. B., Berning, A. (1991) The third-quarter phenomenon: Do people experience stress after stress has passed?. In A. A. Harrison et al. (eds.), *From Antarctica to Outer Space* (261-265). New York: Springer-Verlag Inc.

[4] Bender, H. E., Fracchia, J. (1971). *Habitability system environmental requirements and design guidelines for group stability* (Report No. NAS 9-10998). Houston, Texas: Concept Applications, LTD.

[5] Brown, G., Crossley, C., Robinson, S. L., (2014). Psychological ownership, territorial behavior, and being perceived as a team contributor: The critical role of trust in the work environment. *Personnel Psychology, 67,* 463-485. doi: 10.1111/peps.12048

[6] Do, S., Owens, A., Ho, K., Schreiner, S., de Weck, O. (2016). An independent assessment of the technical feasibility of the Mars One mission plan – updated analysis. *Acta Astronautica, 120*, 192-228. doi: 10.1016/j.actaastro.2015.11.025

[7] Littlepage, G. E. (1991). Effects of group size and task characteristics on group performance: A test of Steiner's model. *Personality and Social Psychology Bulletin, 17*(4), 449-456.

[8] Maltby, J. (2010). An interest in fame: Confirming the measurement and empirical conceptualization of fame interest. *British Journal of Psychology*, *101*(3), 411-432. doi:10.1348/000712609X466568

[9] Mars One. (n.d. a). Roadmap. Retrieved from http://www.mars-one.com/mission/roadmap

[10] Mars One. (n.d. b). Norbert Kraft. Retrieved from http://www.mars-one.com/about-mars-one/team/norbert-kraft

[11] Mars One. (n.d. c). What is the Mars One business model?. Retrieved from http://www.mars-one.com/faq/finance-and-feasibility/what-is-the-mars-one-business-model.

[12] Moore, J. H. (2001). Evaluating five models of human colonization. *American Anthropoligist, 103*(2), 395-408.

[13] Musk, E. (2016, September). *Making humans a multiplanetary species*. Presented at the meeting of the International Astronautical Congress, Guadalajara, Mexico.

[14] Musson, D. M., Sandal, G. M., Helmreich, R. L. (2003). Personality characteristics and trait clusters in final stage astronaut selection. *Aviation, Space, and Environmental Medicine 75*(4), 342-349.

[15] Palinkas, L.A., Gunderson, E.K.E., Holland, A.W., Miller, C., Johnson, J.C. (2000). Predictors of behavior and performance in extreme environments: The Antarctic space analogue program. *Aviation, Space, and Environmental Medicine, 71*(6), 619-625.

[16] Pierce, J. L., Jussila, I. (2010). Collective psychological ownership within the work and organizational context: Construct introduction and elaboration. *Journal of Organizational Behavior, 31*(6), 810-834

[17] Sherif, M. (1956). Experiments in group conflict. *Scientific American, 195*, 54-58

[18] Smith, C. M., & Davies, E. T. S. (2012). Emigrating beyond earth: Human adaptation and space colonization. New York: Springer.

[19] Slobodian, R. E. (2015). Selling space colonization and immortality: A psychosocial, anthropological critique of the rush to colonize mars. *Acta Astronautica, 113*, 89-104. doi:10.1016/j.actaastro.2015.03.027

[20] Stuster, J. (1996). Bold endeavors: Lessons from polar and space exploration. Annapolis, Maryland: Naval Institute Press.

[21] Tajfel, H., Flament, C., Billig, M. G., Bundy, R. P. (1971). Social categorization and inter-group behavior. *European Journal of Social Psychology, 1,* 149-177.

[22] Wang, Y., Jing, X., Lv, K., Wu, B., Bai, Y., Luo, Y., Chen, S., Li, Y. (2014). During the long way to Mars: Effects of 520 days of confinement (Mars500) on the assessment of affective stimuli and stage alteration in mood and plasma hormone levels. *Plos One, 9*(4), 1-9.

BIOGRAPHY

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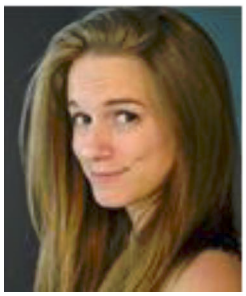

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