Futures 117 (2020) 102514

Contents lists available at ScienceDirect

Futures

journal homepage: www.elsevier.com/locate/futures

Essays

Visions of a Martian future

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ARTICLE INFO

Keywords:
Mission to Mars
Mars settlement
Space philosophy
Space ethics
Space policy
Future studies

ABSTRACT

As we look beyond our terrestrial boundary to a multi-planetary future for humankind, it becomes paramount to anticipate the challenges of various human factors on the most likely scenario for this future: permanent human settlement of Mars. Even if technical hurdles are circumvented to provide adequate resources for basic physiological and psychological needs, *Homo sapiens* will not survive on an alien planet if a dysfunctional psyche prohibits the utilization of these resources. No matter how far we soar into the stars, our psychologies for future generations will be forever tethered to the totality of our surroundings. By shaping our environment toward survival and welfare during the voyage to Mars and in a Martian colony, we indirectly shape our psyches and prepare them for a mission of unprecedented alienation and duration. Once on Mars, human factors such as leadership structure, social organization and code of conduct, group size, gender balance, developmental cycle, mobility, length of stay and the ecological settings and type and manner of subsistence, will create a novel Martian culture. The degree that settlers are severed from the Earth will affect how radically foreign this culture will be when compared with cultures on Earth.

1. Introduction

The recent expansion in number of privately funded space programs has galvanized the public's desire for space exploration that will fulfill the vision of a multi-planetary future for humanity. Ambitious plans of creating the first human settlement on Mars are frequently presented as the next proverbial giant leap for humankind (Szocik, Lysenko-Ryba, Banaś, & Mazur, 2016). Mars One, a proposed one-way mission to Mars to establish the first human settlement, has been the topic of much public attention. SpaceX CEO Elon Musk has recently communicated his vision for humans as a multi-planetary species (Musk, 2017). Rationales for such a mission

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https://doi.org/10.1016/j.futures.2020.102514
Received 27 November 2019; Accepted 12 January 2020
Available online 15 January 2020
0016-3287/

are not obvious, especially when contrasted with the financial burdens and political determinants (Szocik, 2019). One additional issue is also the long-standing debate between the value of human *versus* robotic missions (Szocik & Tachibana, 2019). However, the underlying question of whether or not to go to Mars no longer seems germane given the current serious plans of some space agencies and innate human desire for exploration. Despite some overly optimistic predictions and perhaps willful ignorance of possible obstacles, the critical questions now concern *when* and *how* humans will begin their odyssey to the Red planet.

In this paper, we will discuss significant challenges facing currently planned human missions to Mars. Among the most obvious are medical and technological challenges, which are a prelude to more complex ethical, social, anthropological, and evolutionary challenges. We propose that the human factor on a mission to Mars is simultaneously both the most integral and most vulnerable aspect of that planned enterprise. We refer not only to human biological and physiological vulnerability but also to the broad set of factors that encompass human mental, social, ethical, and political life. We discuss selected issues that should be taken into account by every planner of a mission to Mars who conceives of such a mission as a long-term enterprise or even a future settlement for humans beyond Earth.

Our multidisciplinary paper is aimed at analysis of selected aspects of the human factor in space, which may also include human cultural creativity, ethical codes, and religious beliefs. Given the history of religion on planet Earth, we believe that any founding social structure or government should be secular in nature, but, at the same time, allow for a wide spectrum of religious expression among colonists. We believe that it is worth considering these issues as a multi-planetary human species may provide a blueprint comprising living records of cultural and biological evolution from Earth to the outer planets. We surmise that upon the establishment of a Martian society, humans will organize their lives following schemas both derived from evolution of cultural forms on Earth, but adapted to create new schemas for meeting the challenges of life on Mars. While our paper is far from a comprehensive analysis, we believe that our considerations will add value to future studies regarding the possible challenges and consequences of efforts to transform humanity into a multi-planetary species, However, we are not aligned with the approach described by Richard Tutton as “multiplanetary imaginary” (Tutton, 2018). Whereas Tutton’s term describes a utopian projection of desired future reality, our paper focuses on identifying and analyzing various challenges associated with the human factor in space and on planets and moons of the solar system, using extrapolations from human history on Earth.

2. Destination Mars

There are numerous reasons why humans should wish to visit and potentially settle on Mars. This includes satisfying the innate human desire to explore, through to the perceived need to preserve humanity from existential catastrophe on Earth, be it natural or man-made or a hybrid of the two. Earth has faced numerous catastrophes which include mass extinctions and yet there still may be difficulties regarding political justification for the enormous investment needed to fund a space refuge (Szocik, 2019), as it may be expected that such a refuge might be discriminatory and be designed for people representing space-faring countries, or the particulars of access to these refuges may at least be dictated by these countries. While this scenario seems far from a just and fair solution, it is in accordance with the historical distribution of power and resources on Earth. The idea of global unity and a joint effort of the entire world community in space exploration may mask imperialistic attitudes of some of the political powers behind various space agencies (Messeri, 2016, Introduction). The solution would be emergence of a global space-faring ethos committed to open competition, equal access, and an ethical charter guiding all. These are lofty goals, and will be difficult to achieve in the near term.

Messeri shows, from an ethnographic perspective, how planetary scientists work on Earth to contribute to the creation of perceptions of the outer planets. Messeri uses the term *planetary imagination* to express this social, cultural and political construct. Her remarks are of high value, because our attitudes towards Mars can only be shaped by narrations created on Earth by authors of science fiction, scientists, philosophers and politicians. Planetary scientists make great efforts to reconstruct and to “metamorphose the dark expanse of the night sky into a zone of fresh meaning and insight” (Messeri, 2016, Introduction). Current images of Mars are the products of cultural history, social process, human judgments and pre-judgments and calibration of scientific instruments (Vertesi, 2015, Chapter 2). Even today, there is no consensus about life on Mars and uncertain consensus on how to interpret scientific data (Weintraub, 2018, Chapter 1).

Motivations for settling Mars vary. Some have raised the issue of the desire for an exit strategy from Earth (Valentine, 2012), discussed the problems of biological contamination from Earth affecting the science of an “original” or pristine Mars (Fairén, Parro, Schulze-Makuch, & Whyte, 2017), or simply suggested that Mars should not be settled (Billings, 2017). Dangers to humans have been discussed, although after Earth, Mars is arguably the most hospitable planet in the Solar System. Some recent authors have injected a note of realism, claiming that Mars is probably “an awful place to live” (Cockell, 2002). This is a real likelihood, but remains the primary and perhaps only destination where current visions of space settlement and exo-planetary futures are centered. Mars has captured the imagination of scientists, politicians, and the public, not to mention future generations of citizens who will eventually form the crews of space vehicles to Mars.

3. Environmental ethics for Mars exploration

The ethics regarding human settlement of Mars may differ according to whether it is inhabited or not and we summarise our thinking in Fig. 1. We propose the development of an international Earth Charter consisting of overriding principles developed and communicated prior to the commencement of settlement activities. If there is already life on Mars, our proposed charter would mandate us to identify and catalogue species, understand the potential risk posed to colonists such as infection if life-forms are microbial, accommodate their presence and potentially adopt a symbiotic ethical relationship of coexistence and this has previously

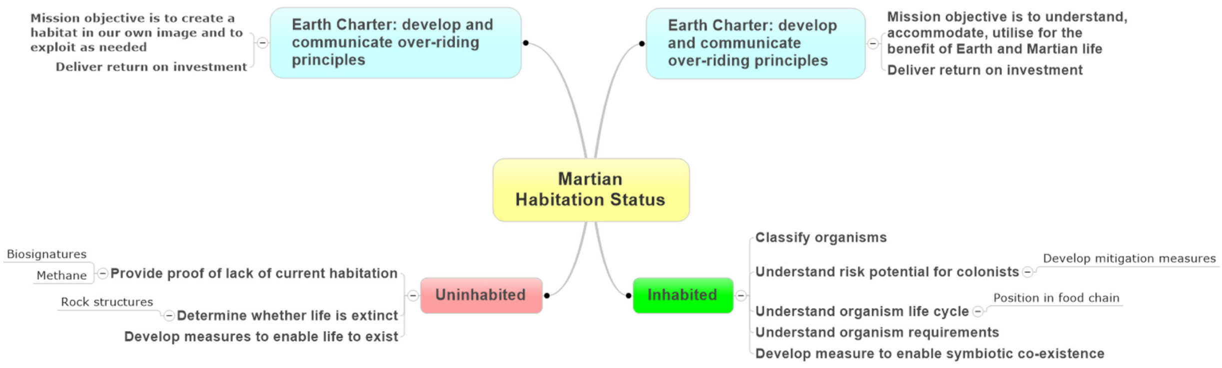

Fig. 1. Settlement strategies towards inhabited and uninhabited Mars.

been described (Callicott, 1992; Cockell, 2004, 2005, 2011a, 2011b, 2016a, 2016b; Ginsberg, 1972; Hart, 2010; Lupisella, 1999; Persson, 2012; Race & Randolph, 2002; Randolph & McKay, 2014; Smith, 2009). We will consider human ethical obligation if there is no life on Mars. How to establish that a world is *uninhabited* is a challenge in its own right (Persson, 2014). We strongly recommend rising to this challenge before humans begin any settlement attempt. Measurement of biosignatures including methane and assessing whether life has ever existed by searching for fossils are such measures which may be employed. The care for possible tracks of life on Mars is one of the main postulates strongly supported by, among others, Christopher P. McKay (2009) and David A. Weintraub (2018). Humans cannot protect everything on Mars perfectly, but they can try to protect what they can, and do so with pragmatism and wisdom.

If we do come to the conclusion that Mars is uninhabited, what then? Here, we argue that when it comes to the question of moral responsibilities, the situation is in fact exactly the same if there is no life on Mars as if there is non-sentient life, namely, that there is nothing on Mars that has moral status in its own right and that any values at stake will be totally dependent on us sentient organisms that regard Mars from the outside (Persson, 2012, 2019). We do not attach intrinsic value to non-life forms and thus, just as would have been the case in early human colonization of Earth, we utilize the Martian landscape to fulfill our mission objectives which are to establish a human settlement and deliver a return on investment to Earth. It should be added that when humans arrive in any new location, they immediately begin selecting the "best spots" and "hallowed ground," so land, vistas, sites and sights may come to assume human importance in the future years.

The scientific value of discovering life on Mars, especially a second genesis of life, would have enormous scientific, economic, and psychological value for humans. Experiments on Earth suggest that Martian minerals could provide efficient anti-radiation protection, including the possibility of radioprotection of biomolecules. To date, there has been limited investigation of using Mars itself as a resource for construction, protection, housing, processing of natural resources for use and sale, and as a source of components for medicines of the future. Making life self-sustaining on Mars has received too little emphasis to date. When humans have colonized all areas on Earth, they use the materials, weather, chemistry and the beauty of local sites of interest and outstanding natural beauty all over the world. Humans make it their own, and they will do so on again on Mars.

4. Can deep altruism sustain space settlement?[1]

To achieve the transition from an earthly species to a multi-planetary one, humankind must cope with a purely earthly, co-operative challenge. The establishment of a permanent human settlement on Mars will require unprecedented cooperation and coordination by successive generations over deep time. This is especially true if the dream of terraforming Mars is undertaken, as the process must be carefully controlled over centuries and maintained in perpetuity. We note that terraforming is a popular concept that is exceptionally difficult and expensive to carry out; more likely, the spread of Mars settlers would continue to be in self-contained habitats. The technology to enable space settlement thus requires parallel advances in ethics in order to sustain such ambitious long-term efforts. Innovative approaches to financing and management provide further means of enabling space settlement, as even commercially driven space activities require significant investment and time before realizing any profits. As an alternative approach, the concept of *deep altruism* provides a model that contrasts with commercial or colonial motivations for exploration by valuing the well-being of others in the distant future over any benefits to self.

Time capsules serve as an illustration of a long-term effort for the benefit of others in the future. The construction of a time capsule is always intentional, although the time horizon can vary: "target-dated" time capsules specify a particular date to open the capsule, while "deliberately infinite" time capsules are intended to remain preserved in perpetuity or for an indefinite period of time (Jarvis, 2002). Successive generations must preserve knowledge of the capsule's location and the relevance of its contents in order for its full value to be realized. A time capsule with a target lifetime on the order of a millennium would be an example of an altruistic

[1] This section is a slightly modified and shortened version of the following chapter: Haqq-Misra, J. 2019. Can deep altruism sustain space settlement? In K. Szocik (Ed.), The human factor in a mission to Mars, space and society. Cham: Springer.

effort that attempts to operate over deep time. Space settlement likewise represents an intentional and deliberately infinite effort that must maintain its informational relevance across generations in order to realize its full future value. Part of this relevance would stem from the settlers archiving instructions for others on how to survive and persist in an unknown environment. It is interesting to note that one project now under construction – the Clock of the Long Now – which is meant to operate for ten thousand years and hence change our perspective on deep time, is partially supported by Jeff Bezos, founder of the commercial space company Blue Origin. Since the latter has as one of its goals the expansion of human settlement beyond Earth, both ventures call on humans to think in terms of deep time.

As a way of comparing long-term human efforts, value theory provides a way to construct a comparative hierarchy for long-term projects based upon cultural, structural, and informational value. Cultural value is foundational to all human endeavors and represents the preservation of tradition, aesthetics, and other central features of the group's identity. Examples of long-term efforts motivated by cultural value include literature, art, religious traditions and genealogies. Structural value refers to the preservation of materials, buildings, or other feats of engineering; structures can be motivated by utility (*e.g.*, shelter or storage) as well as by cultural factors (*e.g.*, temples or shrines). Informational value describes the realization of cultural and structural factors to provide long-lasting benefits to human knowledge and enable solutions to major problems. Some long-term informational projects require direct support by significant infrastructure, such as "big science" projects in physics and astronomy that typically require two decades to complete – five decades in the search for gravitational waves. Other examples of efforts motivated by informational value include the human genome project, the projected recovery of the Antarctic ozone hole, and the long-term management of investment trusts. This three-tiered value scale provides a framework for comparing the relative value of long-term human projects.

The completion time for a project is defined as the duration between initial conception and final execution. Some efforts have a completion time within a single generation, between about 10 and 100 years, such as building a city, implementing a new technology, or completing a typical scientific study. Generational projects tend to have a target date for completion, although deliberately infinite generational efforts that succeed will continue beyond the lifetime of the founder to the next generation. The completion time for inter-generational efforts is about 100 to 1000 years; examples of target-dated inter-generational efforts include the construction of ancient cathedrals, temples, and palaces that remain standing today. Other inter-generational efforts are deliberately infinite, such as the uninterrupted efforts of a handful of libraries and investments. Any inter-generational efforts that successfully adapt to change over centuries will eventually approach the threshold of deep time, when the completion time reaches the scale of 1000 years or longer. Navigating an intentional effort through deep time requires contending with changes in geopolitics, climate and other factors that are usually neglected at shorter timescales. The few examples of successful projects across deep time include the construction of the Great Wall and Stonehenge as well as the continuous maintenance of the oldest genealogies. Few, if any, efforts have successfully realized informational value across deep time. The settlement of Mars and other regions of space represents the pursuit of informational value over deep time, with an effectively infinite duration. Although the timescale for achieving an initial human presence on Mars may be generational, any long-lasting and autonomous space settlement must develop a strategy for inter-generational succession to succeed over deep time.

Deep altruism can now be more precisely defined as the selfless pursuit of informational value for the well-being of others in the distant future. An assortment of human projects has succeeded over inter-generational or even deep time – including cathedrals and other structures motivated by religion – but none has managed to achieve informational value with a millennial-scale completion time. Some efforts, such as the Clock of the Long Now, are motivated by altruistic intentions of preserving value across deep time; however, such efforts are presently in the initial generational phase where the founders are still alive and active. Any effort motivated by deep altruism will require the successful succession of leadership and management in order for the effort to transition into intergenerational and deep timescales.

Deep altruism by individuals, private donors, or organizations represents an extreme non-reciprocal form of altruism, where the actions taken by the founders are unlikely to confer any direct benefits to themselves or direct descendants. Although other animals exhibit varying degrees of reciprocal altruism (Trivers, 1971), non-reciprocal forms of altruism appear to be unique to humans and perhaps a few other primates (Brinkers & den Dulk, 1999; Johannesson & Persson, 2000; Takahashi, 2007). A benefactor acting out of a sense of deep altruism would forego any personal recognition in favor of a vision for the human species that extends far into the future. Non-reciprocal altruism may be a uniquely human response to the problems caused by civilization itself; deep altruism may therefore serve as an approach toward enabling a better long-term future for humanity.

The antithesis to deep altruism can be approximated as "deep egoism," which represents a long-term investment in the future for the benefit of self, kin, and colleagues over others. Many efforts at profiting from space resources are rooted in deep egoism, with the expectation of long-term profits to shareholders willing to bear the risk of investment today. Deep egoism resonates with modern capitalist ideals, although it may be unable to sustain deliberately infinite operations if unable to also continually provide a return on investment. Benefactors and funding agencies can take steps toward enabling alternative approaches to the settlement of space by providing opportunities to pursue projects of informational value with completion times on the scale of decades or longer. Commercial interests will remain an important factor in the new-space arena, but deep egoism alone may be insufficient to establish an autonomous and sustainable human presence in space. The success of a permanent human settlement of Mars depends upon effective succession across generations, which will require new institutional governance models driven by deep altruism.

We are aware of the fact that the model of deep altruism presented here may lead to skepticism about the altruistic potential of humanity expressed in biological terms of action. This biological understanding of altruism focused on the idea of minimizing someone's reproductive fitness for the fitness of others is counterbalanced by sociocultural anthropological understandings of altruism. This sociocultural approach is centered around theories of the gift (Mauss, 1925). Marcel Mauss's essential point is that altruism or gift-giving is always part of some form of exchange and while it certainly conveys and enacts care for others or future generations, it is not and cannot be entirely separated from self-interest in that the gift always sets up relations of reciprocity, even if they are not demanded by the giver (and even if the giver is not around to receive a benefit, those reciprocal relations endure). It is worth keeping in mind this important cultural theory of human behavior, which currently is expressed by biologists who question the existence of unselfish behaviors and altruistic cooperation. But, as we tried to demonstrate, humans, at least in some situations, may be an exception and may be able to realize altruistic effort.

It is worthwhile to add that the broad set of ideas discussed in this section includes, among others, the important issue of the temporal, generational layer in ethical considerations connected with responsibility and sustainability. One category of ethics regarding Mars might relate to the needs (physical, psychological, or moral) of the current generation, *versus* the needs of much later generations. Would a later generation despise our current generation if we did not exercise sufficient care in preserving Mars (for example), or conversely would they despise us if, in our efforts to preserve Mars as it is for the future, we inadvertently lapsed in efforts to prepare it for settlement in the face of an Earthly emergency? This topic combines the project of sustainable development with environmental ethics and when we refer to Fig. 1, we may envisage that our plans for utilizing an uninhabited Mars are centered around deep egoism, in contrast to the need to accommodate life forms in an inhabited Mars which may have a greater deep altruistic component

Mars has a similar land area to Earth and so has similar levels of raw solid resources (although, lacking plate tectonics, the geological processes that concentrate these resources are diminished on Mars). Use of those resources is likely to grow at an ever-increasing rate. On Earth, resource use is *via* an economy that grows exponentially (*i.e.*, like compound interest). Iron production has doubled every 20 years, on average, since the beginning of the Industrial Revolution around 1800 C.E., and is now about 1000 times what it was in the pre-industrial world. If human use of Mars resources grows similarly, then we can estimate that our Martian descendants will be nearing the limits of their world two to three centuries from now. That puts a scale on the deep time that applies to Mars.

5. The challenge of the study of the human factor in a mission to mars

The study of human space exploration, primarily when referring to planned but yet-to-be realized missions, entails an obvious methodological challenge. One of the basic tools that is used in this field is study by analogy. By analogy we refer here to particular conceptual tools, methodologies, and fields of knowledge applied to a partially unknown space environment. That partial lack of knowledge is the "tragedy" of space scientists. On the one hand, we possess knowledge based on the time astronauts have served in space to date, mostly on ISS, or information gathered from satellites and Martian probes including the recently launched NASA InSight Mars lander. We have detailed information on the Martian atmosphere, temperature, and cosmic-ray exposure. On the other hand, no one can be sure how the human body and psyche will react over the long term in the Martian environment, for the following reasons. First, genetic variation amongst astronauts may result in candidates that will differ in their resistance to various ecological factors and consequently, in their fitness. Second, we cannot exclude the possibility that some mission planners in the future will attempt to enhance pre-launch crew. It is possible that gene editing and other methods including brain-computer interfaces will be applied in some version for the purpose of future human Mars missions. If enhancement through these means or others is introduced, enhanced human beings may behave and react in a deep-space environment in a different way from non-modified astronauts. This eventuality reduces the accuracy of prediction of human survival, behaviors, and reactions in the context of space settlement.

One constructive analogy that may express the ethical and philosophical complexity of the aforementioned challenges is the current debate between advocates and opponents of extended evolutionary synthesis (EES) (Futuyma, 2017). Advocates of EES argue that developmental biases such as niche construction or plasticity should be treated as evolutionary processes equal to mutation or natural selection. Opponents argue that modern evolutionary synthesis (standard evolutionary theory), based on genetic drift, mutation, migration, and natural selection, explains all possible evolutionary processes (Laland et al., 2014). Analogies to a planned human Mars mission – of very long time scales where some form of expedited evolution might come into play – must address these opposing notions. Their common cornerstone is the rather obvious observation that humans are not adapted to live in space. Supporters of EES would state that we should not modify future deep-space astronauts, since their life-support system is a uniquely efficient and acceptable long-term solution in analogy to evolution. We can call it the equivalent of niche construction.

Opponents of the EES view would support the idea of human enhancement including even radical modification of humans. Currently, this scenario is known only in science fiction stories and is not yet realized in a more radical sense as, for instance, in some forms of gene editing. Gene editing includes somatic genetic therapy, usually accepted and practiced and germline genetic therapy, usually forbidden and controversial (Hughes, 2018). Usually philosophers and ethicists discuss the challenges of possible future human enhancement based not only on gene editing, but also on nanotechnology, robotics, and cognitive science (Roco & Bainbridge, 2003). It is interesting that one of NASA's reports mentions genetic therapy, genetic engineering, and cloning, but adds that these methods are neither applied nor ethically acceptable in the context of spaceflight (Allen et al., 2003). The authors add that gene editing could be applied to enhance human physical and sensory capabilities like vision or touch. Human enhancement in space has been discussed by Manfred E. Clynes and Nathan S. Kline. They argue that "altering man's bodily functions to meet the requirements of extraterrestrial environments would be more logical than providing an earthly environment for him in space" (Clynes & Kline, 1960). This provocative statement can engender a discussion in regard to a human Mars mission, for at least two reasons. First, we might agree that increasing the chances for survival of deep-space astronauts in a hostile Martian environment – by utilizing all available technological and scientific means – is a reasonable endeavor. One thing that comes to mind is then a complete re-invention of humans to enhance performance in various ways. However, this presents a moral and ethical challenge to the implicit assumption of an immutable human "nature," or at least "nature" protected against deliberate human manipulation (Szocik, Campa, Rappaport,

& Corbally, 2019). Second, the obvious fact that the Mars base will likely not be a self-sustainable human settlement in the short term, and perhaps ever, challenges the idea of the human Mars mission itself. If we cannot build a self-sustainable Mars base to support humans in their present state, then we will have to provide all resources from Earth or, find a closer source of materials such as asteroids. In this scenario, a Mars base will not offer any benefits excluding possible scientific discoveries and an impetus to more rapid technological progress. However, those putative benefits may be easily counterbalanced by the high economic costs of such an enterprise, mostly when confronted with increasing earthly threats including, among others, overpopulation and environmental pollution. The financial costs associated with ameliorating these challenges pose a challenge to the imperative of such a bold space mission, especially given the hostile extraterrestrial environment. In some sense, it is essential that a human settlement on Mars have a viable business model. At first the profit may be from settlers, as no valuable potential export from Mars is known. Even in a hypothetical post-capitalist, post-scarcity era, profit-making would be a way of assessing whether an activity creates value and should maintain a continued level of investment until it becomes self-sustaining.

Sociocultural anthropology as a study of patterns of behaviour and cultural meanings, traditionally focuses on the group's distinctive characteristics and the ways people understand other groups as well as the world. While the human societies form naturally, the crew selection is an intentional selection process guided by a number of physical, mental, medical, intellectual, and cognitive requirements. The same is the case for Antarctic expedition planning, pilot training, astronaut selection, or even team building on Earth. A specific combination of experience and skills are needed for a safe operation and successful completion of a mission or a complex project.

In imagining the manned mission to Mars - and the development of the very first Martian society and the first culture beyond Earth - we need to consider a number of factors that will contribute to the group formation and cohesion. Those factors may be crucial in handling the disturbances in the functioning of the Martian settlement. The group size, type of leadership, social organisation and gender balance will affect the group dynamics and ability to create a sustainable human presence on Mars. The ecological settings and especially the settlements dependance on terrestrial supplies, or the ability to provide independent and reliable means of subsistence will be crucial for groups survival and well-being. A new distinct Martian culture as well as a cultural practice of adaptation and survival (Franklin, 1995) will be formed: a new "culture of science" as a first step in the development of a skilled and knowledgeable culture that will likely be driven by the ethos of discovery. Such culture will expand the geographical exploration beyond our native planet (Capova, 2016).

Creating a settlement on another planet will bring a reinvention of what we know about the ways of life and daily routines but also an unprecedented way of understanding Earth. Appearing as a bright star on the Martian night sky, the home planet Earth will be over thirty million miles far away. Will the well-being and mental health of humans be affected by such extreme detachment? Many astronauts have reported the "overview effect" (White, 1987), a strong emotional response to seeing the Earth from outer space. The overview effect is a profound shift in their thinking about Earth and humanity, often recognising its fragility. While some authors emphasize the optimistic scenario of effective adaptation to live in space (Smith & Davies, 2012), others consider almost unrecoverable detachment from the unique natural terrestrial environment (Cohen & Haeuplik-Meusburger, 2015). This may be true also for the rather unpredictable effects of the cognitive shift experienced on Mars.

6. Martian environmental psychology: the choice architecture of a mars mission and colony

The first voyagers who venture to Mars and seek to live on soil beyond our terrestrial home will face an environment mismatched with the one in which their genomes, epigenomes, and psyches evolved. Environmental psychology can be employed to shape the choice architecture of a vessel to Mars and a colony upon it, in order to bias choices toward the fulfillment of fundamental existential, relationship, safety, and fitness needs. Aspects of surroundings that could be engineered to create psychological states optimal for survival and welfare include primes, defaults, private spaces, shared spaces, windows, color, nature, pets, light, noise, temperature, odors, contaminants, order, and diversions.

A human organism that perishes due to a dysfunctional psychology is just as dead as one that perishes due to a failure in biology. All the resources in the world are useless without the will to utilize them. Too often we fail to survive not because of a lack of resources, but due to a lack of resourcefulness. And this lack of resourcefulness emanates from non-optimized psychological states, which makes the organism vulnerable to cognitive and emotional storms. In laboratory experiments, if animals reach a frustrated psychological state in which they believe there is nothing they can do to survive (termed "learned helplessness"), they fail to use the resources available to them to do so (Maier & Seligman, 1976), (Sweeney, Anderson, & Bailey, 1986). A Mars colony will perish if depression and helplessness strip the colonists of their will to survive.

How will our terrestrial psychology face these challenges amidst the stars and on Mars? We can draw analogies from polar expeditions and other survival situations and see that it may be necessary to sometimes supplant the whims of the individual in favor of the survival needs of the group (Szocik, Marques et al., 2018). Although much has been said about the selfish gene, even cooperation entailing self-sacrifice may ultimately serve selfish ends through mechanisms such as kin selection (Wilson, 1975). Evolutionary drivers of behavior such as this are difficult to oppose. How can we augment this cooperation and other sociological and psychological attributes that will encourage mission success through an engineered environment? As we strive for cooperation to facilitate survival, how can we encourage cooperation in the least coercive manner possible? Much of our recent enlightenment as a species has involved the importance we place on the freedom of the individual. Can we encourage cooperation by suggestion rather than coercion? It would seem to be one step forward for humankind and two steps backward if we were to establish a Mars colony on the foundation of despotism – relatively likely future scenarios of tyranny, human exploitation, and dictatorship in a remote space environment considered by Cockell (2015, 2016a, 2016b). However, some authors hope that the hostile space environment will enhance prosocial human biases and enforce close collaboration (Lockard, 2014). As we balance the existential need for our species to live, with our preference to live well – that is, to live freely – environmental psychology can play a role in maintaining freedom to choose while increasing the likelihood that those choices will serve both the individual and the group.

Environmental psychology refers to how our surroundings affect our psyches and behavior (Ittelson, Proshansky, Rivlin, & Winkel, 1974). Physical structures can enable and influence the direction of thoughts, moods, and behaviors. Choice architecture is a related concept and refers to the design of how different choices are presented to us which can make it more or less likely for us to choose a certain path (Scheibehenne, Greifeneder, & Todd, 2010).

Priming influences behavior by exposing a person to one stimulus, which then biases his or her response to subsequent stimuli (Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trötschel, 2001). Visual primes that seek to facilitate survival and welfare behavior could include messages on physical displays projected onto walls of private living quarters, displays embedded in biomechanical enhancements, wearable technology, virtual reality or augmented reality. Likewise, since our cognitive heuristics bias us to accept the default position (Samuelson & Zeckhauser, 1988), defaults that conserve resources and promote the health and welfare of the entire community can be engineered up front.

Satisfying the need for solitude in private spaces and sociality in public spaces can be engineered through the adoption of a modified Panopticon architectural design, where living quarters comprise the circumference of a space, with access to a shared space in the center. When it comes to the establishment of close relationships, proximity is destiny (Segal, 1974), (Festinger, Schachter, & Back, 1950) and such a design would ensure that everyone would be more or less equally likely to mix with everyone else in the shared space in a kind of Arthurian egalitarianism. Like the Knights of the Round Table, no person would be isolated at the ends. And because of the circular design devoid of interior private sleeping quarters, each sleeping quarter would enjoy an outward view, necessary for the orientation of time and place, and to present novel stimuli to avoid the hallucinations concomitant with isolated environments (Arzy, Seeck, Ortigue, Spinelli, & Blanke, 2006). Even symbolic territorial demarcations can lower the psychological stress of crowding (Brown, 1987).

Colors reminiscent of nature, such as the blue of a wide open sky or the green of a forest, may serve to enhance the mood of travelers and colonists due the concept of biophilia, an evolutionary aesthetic theory proposed by E. O. Wilson to describe the innate tendency of humans to seek out nature and other forms of life due to their fitness benefits (Wilson, 1984). Like natural scenery, pets have also been part of humanity's evolutionary past (Losey et al., 2011). Immunoglobulin A levels were boosted in study participants who petted a dog but not a stuffed toy dog (Charnetski, Riggers, & Brennan, 2004; Nagasawa, Kikusui, Onaka, & Ohta, 2009) and pet ownership decreases blood pressure responses to mental stress (Allen, Shykoff, & Izzo, 2001). On a Mars mission and colony, since resource allocation will prioritize humans over pets, artificial pets with an embodied artificial intelligence may serve as a substitute in order to conserve resources.

A study of the sleep patterns of 21 astronauts over 3248 days of long-duration spaceflight on the International Space Station, including 11 days prior to launch, which used physiological measuring devices and reviewed sleep logs to determine sleep medication use and sleep quality, revealed that sleep was often disrupted due to electronic tablet use before attempting to sleep (Flynn-Evans, Barger, Kubey, Sullivan, & Czeisler, 2016). Rational environmental design that facilitates sleep-promoting behaviors, such as wearable technology or sound proofing of structures and comfortable temperatures, can help prevent poor decision-making resulting from depressed mood, willpower, and cognitive function arising from deficient sleep.

Odors can be engineered to optimize mood: inhaling green odor (a 50:50 mixture of trans-2-hexenal and cis-3-hexenol) has been shown to have an inhibitory effect on the stress-induced activation of the hypothalamo-pituitary-adrenocortical axis in humans (Oka et al., 2008), and to alleviate depressive states in rats by increasing brain-derived neurotrophic factor (BDNF) in hippocampal regions (Watanable et al., 2011).

Since people tend to act more unruly in disordered environments (Wilson & Kelling, 1982), norms should be established before the mission regarding the order of private and shared spaces.

Boredom must also be avoided, and diversions in public spaces on a Mars mission in the form of games and other activities, including those that involve human touch, will likely be important for the satisfaction of relationship needs. Some nonhuman primates spend up to 20 percent of their time grooming to facilitate interpersonal bonds, and in a recent study of sports teams those that spent more time touching one another performed more successfully (Kraus, Huang, & Keltner, 2010). Touch dampens the stress response and increases levels of oxytocin while decreasing blood pressure (Coan, Schaefer, & Davidson, 2006; Light, Grewen, & Amico, 2005).

On this strange Martian journey and land, psychological vulnerabilities will be magnified. To adapt to the first journey in which we seek to live beyond the soil of our terrestrial home, we must shape our psyches by shaping our environment. Only then can we shape our future.

7. Living on Mars: when we become aliens[2]

In the context of current human achievements in space-exploration programs, and our current technological limitations, the concept of societies living on Mars sounds like science fiction. We spend our lives pinned to planet Earth. In half a century of human space flight, fewer than 600 people have been to low Earth orbit, and just 12 have stood on the surface of another world. The cost and

[2] This section is a slightly modified and shortened version of the following chapter: Impey, Ch. 2019. Mars and Beyond: The Feasibility of Living in the Solar System, In K. Szocik (Ed.), The human factor in a mission to Mars, space and society. Cham: Springer.

difficulty of extracting humans from gravity's grip seem to have put dreams of living off-Earth on ice.

Yet that is changing. Space entrepreneurs Elon Musk and Jeff Bezos are perfecting reusable rockets that might ferry people more frequently and cheaply into orbit, and Musk announced with great fanfare in 2016 plans for a large rocket to ferry people to Mars. NASA plans have included sending astronauts to Mars by 2035, and China also intends to build a lunar colony followed by a Mars colony. These plans are enabled by technological innovation. New materials allow rockets to be lighter, stronger, and cheaper to launch, as does the profit-driven design philosophy of Musk and Bezos. Replacement parts can be fabricated by 3D printers in Earth orbit. It is a low-tech process in principle to turn the Martian soil into construction material and mine it for water to drink and oxygen to breathe or use as rocket fuel, even if the first attempt at Martian resource extraction, the MOXIE experiment on NASA's Mars 2020 mission, is turning out to be surprisingly complex.

Suppose this plays out in the next fifty years. We can imagine the first baby born on Mars. How will living there change us as humans? Several cosmonauts and astronauts have spent more than a year continuously in microgravity, and they experienced muscle loss, reduced bone density, and difficulties with vision. Settlers on Mars would experience reduced gravity. Their capillaries and cardiovascular systems would adjust, perhaps not in a good way, and muscle mass would be shed in the absence of special exercise regimens. Few would relish living in the isolation and close confines of a "bubble habitat" far from home. The lack of a varied natural environment is likely to lead to weaker immune systems. However, the settlers will innovate. With space suits made from materials that are supple, supportive, and skin-tight, we might envy their ability to effortlessly leap and cavort across the surfaces of their new world.

If early settlements are restocked with new recruits from Earth, physiological changes will be modest. But subsequent settlers may sever the umbilical; they might be dissidents or driven by utopian ideals, or simply compelled by the difficulty of resupply. As they live and die off Earth, their psychological landscape will be sculpted by their new environment. In time, they could evolve into a new offshoot from the human tree. The minimum size of a viable colony, one that avoids excessive genetic abnormality and inbreeding, is about 100–150 (Smith, 2014). Most likely the settlement should be larger to be stable. Anthropological studies of small-scale societies show that the optimal size of the group should not exceed 100 members, while a smaller size is more reasonable for food collection. This issue will be challenging from the point of view of small societies living on Earth, which – like the !Kung – survived for long periods of time in small, self-sustainable communities (Lee, 1985). But, on the other hand, it is worth keeping in mind population biology. Effective population and minimum viable population are estimated to be no less than 1500 and 3000–5000 respectively (however, these estimates vary). These numbers grow rapidly for interstellar settlement – from 7000 up to even 40,000 individuals in a founding population (Smith, 2014). While Smith's estimations refer to a hypothetical multi-generational interstellar journey, they show that population biological planning even in regard to a Mars settlement should take into account the risk of epidemics and other deleterious effects, which include the dangers of generating a highly in-bred population if new colonists are to the sole progeny of the settler population.

How many doctors should there be? How many engineers who understand the life-support systems? Who will teach the next generation of experts? Such examples can be multiplied many times over. The settlers will be subject to two phenomena that are well known among small, isolated populations on Earth: the founder effect and genetic drift. These effects are present in all populations, but are greatly enhanced at the population level of a likely Mars colony. A shrunken gene pool has the counterintuitive result of accelerating evolution. Evolution may also get a boost from cosmic rays, which – with the combined impact of microgravity – will affect DNA and cause mutations (Moreno-Villanueva, Wong, Lu, Zhang, & Wu, 2017). (With regard to the hazardous impact of space radiation it is worth noting that the main acute threat of radiation in space is not high rates of mutation, but deadly radiation doses). On the other hand, smaller genetic variation has the possible downside of being less able to respond to new selective pressure. Settlers will be vulnerable to new pathogens that could wipe them out. So it is a good bet that they will take control of their own destiny to ensure long-term survival. Technologies for engineering and "editing" DNA are maturing rapidly, so the settlers will optimize their genetic makeup, augmenting Darwin's mechanism of natural selection. Advanced medical technology and an optimized diet will ensure that almost everyone survives to old age, not just the fittest (as will presumably also be the case on Earth).

Martian settlers might in effect not be citizens of any country, as their countries of origin can exert little control over them, so they could set their own legal and ethical regulations. It is likely that they would aggressively adopt technologies for radical life enhancement or for replacing body parts with mechanical equivalents. The merger of man and machine is dystopian to many, but the adoption of cyborg technologies will give the settlers the power to transcend their physical limitations. This in turn will expand the range of "habitable" off-Earth environments for settlement.

In the radically different and controlled environment of a Mars colony, speciation may happen much quicker than it does on Earth. Suppose some of the settlers return to visit Earth thousands of years and hundreds of generations from now. Their language may be unintelligible and their culture unrecognizable, depending on the intervening level of interaction between Earth and Mars. Given the unstable nature of human culture on Earth and the existential threats we face from weapons, habitat degradation, and pathogens, the settlers might return to a wasted planet devoid of people. They might have evolved to be tall and spindly, with pallid skin, small teeth, and no body hair. Or they may come in an extraordinary variety of forms, since human creativity applied to the new genetic toolbox is likely to flourish, both on Mars and on Earth. It will be unsettling for them, and for us too, like looking into an eerily distorted mirror.

8. Conceiving religion in an extra-planetary environment: some dilemmas and paths

Our last scenario in regard to future human Mars missions refers to one of the most influential issues in the framework of biological and cultural evolution: religion. Religious scholars understand "religion" as a set of beliefs and practices aimed at maintaining a horizon of transcendence or a reality dimension beyond the current physical one. Trying to conceive of a religious dimension in a very remote and unpredictable environment invites reflection at multiple levels and raises serious questions about religion's role and function in such extreme conditions. At least three issues arise when conducting such a "thought experiment": the first distinguishes a functional view of religion from the traditional interpretation of religious nature and experience as in some sense "transcendent"; the second considers a "constructed" religion, resulting from a program designed to fit personal and social needs, against a religious idea as a fundamental reality beyond human manipulation; the third considers the contrast between individually and socially oriented religious forms (Oviedo, 2016, 2018).

Religion, but also non-religious cultural forms, may be used to enhance human behavioral patterns which may seem especially useful in the constrained and hard environment of a Mars settlement. Mission planners should take into account the personal religiosity of a future deep-space crew in the process of crew selection (Oviedo, 2019). When the scenario of permanent or semi-permanent Mars settlement is realized – including human reproduction on Mars, which is necessary for self-sustainable human space settlement (Szocik, Marques et al., 2018) – religious and non-religious cultural forms may be an important part of an educational program for children born on Mars (Szocik, 2017). While the role played by religion in the evolution of prosocial attitudes on Earth is unclear – there are both strong advocates and strong opponents of its impact on prosociality (Norenzayan, 2013; Oviedo, 2016) – space settlement would open new opportunities for the application of religious and non-religious cultural forms in prosocial education.

Religious systems may be worthy of consideration due to the fact that long-term deep-space human missions will require multi-faceted sacrifices by astronauts. As Marc M. Cohen and Sandra Haeuplik-Meusburger (2015) suggestively note, astronauts on Mars will be obliged to live all their Martian lives with a restricted diet, in confined habitats without access to a natural terrestrial environment, without separation between work and social life, without family life, and with a highly regimented schedule. As they show, these kinds of stressors are not comparable with extant human expeditions in extreme environments. The aforementioned sacrifices will affect the morale of the crew and might undermine the essence of being human. Religious crewmembers may find justification for their self-sacrifice in their religiosity. This mixed set of psychological and existential deprivations has been discussed elsewhere (Szocik, Abood, & Shelhamer, 2018).

Finally, as was discussed above and elsewhere (Szocik, Wójtowicz, Rappaport, & Corbally, 2020), due to the possible intentional human enhancement of the pre-launch crew or as a result of the evolutionary process ongoing within a Martian population, humans living in a space settlement may acquire new or modified properties. Enhanced or modified humans may differ not only in the physiological sense, but also in the psychological and ethical. It is impossible to predict behavioral outputs of modified humans interacting with the Martian environment. While Mars terraforming by releasing the total resources of Martian CO_2 may be unworkable (Jakosky & Edwards, 2018), human enhancement is promising and possibly the solitary option to increase the adaptability of the future human Mars population. (It is worth keeping in mind that warming Mars would be only the first and dramatically insufficient step to make Mars habitable for humans. While increasing the temperature on Mars is a process estimated to take 100 years, the process of producing an oxygen atmosphere available for human living without life support system is estimated to take at least 100,000 years) (McKay, 2009; McKay, Toon, & Kasting, 1991). For these reasons religion, although declining in Western populations (at least organized religion if not personal faith), is growing on a global scale. As such, it is a viable candidate to support ethics and human social behaviors. Because humans are cultural entities who use cultural traits to organize and rule their lives, religion – as one of the most important cultural constructs of humanity, and which has affected not only individual lives, but also entire communities and states – should be taken into account by mission planners.

9. Conclusions

We seek here to demonstrate that the human factor on a mission to Mars goes beyond medical challenges and technological limitations. Those are obviously very difficult, and we may hypothesize that they will affect deep-space missions at all stages. However, the human factor in a Mars mission appears at the very beginning of the enterprise, in human nature here on Earth, when we ask why we should settle Mars, and when we consider the best ways of appropriately preparing future Mars settlers. Human factors appear at the ethical, political, and social levels. Among those ideas that should be considered is some form of genetic intervention that belongs to the broader idea of a program of human enhancement. The problems arising from "island-population biology" require a minimal viable population. Coping with constant stress, and maintaining core cultural traits, all need to be addressed. The concept of deep altruism may be needed to settle Mars, even to the extent of nurturing a religion of Martian settlement. Ethical dilemmas underlie all these issues. Always looming is the most basic yet fundamental psychological factor which will color all these dilemmas: human attitudes toward a new and unknown planet.

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