ETHICAL ISSUES OF HUMAN ENHANCEMENTS FOR SPACE MISSIONS

TO MARS AND BEYOND

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Abstract
A human mission to Mars is planned by public and private agencies. It is broadly discussed and studied by scientists in such fields as medicine and aerospace engineering. Less attention is being paid by philosophers and ethicists, and social scientists as well. The aim of this paper is to discuss possible ethical challenges and issues, which may appear during a human mission to Mars. We focus our attention mostly on one issue – the idea of human enhancements for space missions. While our case study is mostly a mission to Mars, ethical issues around human enhancement for space are also relevant for other longer-term human expeditions, including Lunar missions, and beyond. Because the space environment is hazardous for humans, it can be expected that new ethical issues concerning the value of human life may appear.
Keywords: Space missions; Space philosophy; Space ethics; Space policy; Human enhancement; Gene editing

This paper discusses the opportunities for human enhancement in future human space missions. While human enhancement technologies are ethically controversial, their application for the purpose of the future human deep-space missions may be necessary procedures. This paper shows that the biggest ethical challenges associated with space missions may appear not on Mars, but on Earth, when decisions about the enhancement of the pre-launch crew are being considered. The paper asks more questions than it gives ready answers, but its purpose is to encourage space agencies, ethicists, and social scientists to engage in a broad discussion on the ethical challenges of a human mission to Mars. Presented study is an original contribution to the broad field of the ethics of space missions which has not been previously discussed by philosophers, ethicists and space policy scientists.

Introduction: An Ethical Context for a Mars Mission

A piloted mission to Mars and Mars colonization are discussed by administrators, engineers, and scientists, mostly in the United States (NASA 2014; NASA 2016; NASA

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2018d). This type of mission is now being seriously planned by public agencies and private companies (cf. NASA 2013; SpaceX 2017). In spite of the seemingly "science fiction" nature of many of these plans, a mission to Mars is likely the next step of human development and expansion regarding outer space (Szocik et al. 2016), (Shelhamer 2017). Human missions to the Moon are again considered by mission planners. However, due to a relatively short distance from Earth, human Lunar missions are viewed as much less challenging for astronauts than journeys to Mars and beyond, which require special attention not only from scientists (including social scientists), but also from philosophers, including ethicists. Along with space medicine experts and engineers, philosophers will identify ethical challenges in both the concept of a piloted Mars mission and its implementation. Even if technical and medical obstacles are successfully resolved in the near future, there remain critical cultural, social, and ethical challenges for human health and biology, which, if not discussed and resolved, may render a planned mission unsuccessful or even dangerous (Szocik et al. 2018a). In such a case, public sentiment could well impede future progress in a space program.

The ethical issues which are addressed in this paper, are complex and rarely result in straightforward answers. Because of this, a risk/benefit framework and sometimes, cost/benefit language are used because spaceflight and off-world human settlement are desirable, worthwhile, dangerous, and expensive, irrespective of the rationale for any single Mars mission (cf. Szocik 2019). It will require enormous public support worldwide to shoulder the financial investment in space. The issue of cost, when it confronts issues of human health and well-being, naturally calls forth ethical questions. Is the effort worth the risk and the cost, for humankind? Is this type of risk to well trained, healthy, and brave humans a desirable course? How will these efforts pay off in terms of benefits for humans? How can we make sure that we are making the right decisions? Finally, because all humans are stakeholders in space exploration, how can we begin a needed, public stakeholder discourse regarding a human mission to Mars?

These are large, overarching questions that will consume humanity for at least several centuries. This paper focuses on the following more immediate concerns about human health and biology: (1) sound approaches toward beginning the discussion of how much risk is acceptable; (2) suggestions for types of deliberative bodies that can address questions of human biological risk in the space enterprise; and (3) frameworks to begin to think about the types of ethical conflicts involving the human body in spaceflight and on Mars. The authors speculate on how the values of the crew for a range of Mars missions might diverge from Earth-based values, and why. Changes in values will eventually vary by the length of the mission, and other factors. It will be useful to contrast a short-term Mars mission, like planting a flag and taking samples, with a longer-term mission dedicated to research, mining, tourism, and settlement. Among the longer-term missions, there will finally be one in which the crew will know that they will never return to Earth.

The set of ethical concerns in future long-term human missions to Mars or other space destinations is very broad. We propose to focus our attention mostly on ethical issues related to human enhancement. We want to show that mission planners should take into account the possibility of artificial biological enhancements for future deep-space astronauts. To date, this challenge remains largely unseen and unspoken, but it may affect substantially not only our moral intuitions and ethical rules but also protocols in public policy. It may even affect the values of populations on Earth.

There are good reasons to assume that human enhancement may be required for human space missions to Mars and beyond. Hazardous space environment including mostly space radiation and altered gravity will affect negatively astronauts during spaceflight and staying on Mars. Currently available countermeasures such as drugs or physical exercise applied on the International Space Station (ISS) may be insufficient during mission to Mars (Szocik & Braddock 2019). This is the starting point for our considerations: as long as the current space medicine cannot provide efficient protection of astronauts during long-term and deep-space missions such as missions to Mars, the idea of human enhancement for space remains a virtually valuable option which should be considered seriously by mission planners. While that idea may be controversial as far as controversial is human enhancement on Earth, it is justified by the fact that under some conditions, human enhancement may be the unique available alternative to prepare astronauts to safe and successful missions to Mars and beyond.

The Ethics of Space Missions: A Literature Review

The ethics of space missions is a well-established field in ethics and philosophy. Some of the discussed topics relate to current problems and challenges, while others belong to the field of futures studies. The idea of human enhancement for space, as discussed in this paper, is a part of space philosophy and space ethics belonging to futures studies. This subsection is an overview of the currently discussed issues in the ethics of space missions. The reader will notice that the topic of human enhancement for space, as proposed in our paper, is an original contribution to the field of space ethics, previously not discussed by other authors. The public is just becoming aware of how pervasive human enhancements could be on Earth, too.

A good guide and introduction to the ethics of space missions and space in general is *The Ethics of Space Exploration* edited by James S. S. Schwartz and Tony Milligan (2016). The authors mention a variety of ethical issues in space, such as the rationale for large expenditures on space exploration, risks to human health and life in space, the issue of contamination and care for pristine space environments, the responsibility for cleaning up space debris, the issue of property and mining rights with regard to space resources, the right to terraform planets, and the question of appropriate space governments (Schwartz and Milligan 2016, p. 2).The beginnings of the ethics of space exploration date back to 1985 when scholars started to apply environmental ethics to space, the principal objective being to consider issues such as moral rights to explore space (space as an intrinsic value or an instrumental value open to human exploitation) (Hempenius and Voute 1985; Hargrove 1986).

One of the topics discussed within the ethics of space missions is a debate between the advocates and opponents of human missions to space. The question arises, i.e., what humanity should do to do first – protect Earth instead of colonising space, or implement a human space programme? (Munévar 2016). Space ethicists discuss the issue of the rationale for space exploration. Some of them argue for an emphasis of space exploration over space development, but these two are in conflict (Schwartz 2014). Some scholars claim that scientific exploration has an intrinsic value and it gets an absolute priority over resource exploitation and space settlement (Schwartz 2020). It is interesting that the idea of a "space refuge" is criticised for economic, technological, or social reasons, as an ineffectual approach compared to terrestrial refuges (Baum 2009; Baum et al. 2015; Szocik 2019). While some philosophers agree that space settlement is the ultimate solution to save the human species in a long-term perspective, they argue that the colonisation process should be postponed for economic, technological, and ethical reasons (Szocik 2019), or because of the basic conflict between scientific exploration and space settlement (Schwartz 2019a). James S. J. Schwartz (2019a, 2019b) offers several strong arguments supporting the idea that scientific exploration of space in the short- and medium-term should precede space settlement in the long run. Other authors emphasise the potentially adverse social and moral long-term effects of human space settlement, such as in-group conflicts, aggression and violence (Torres 2018). Others recognise space re-settlement as indispensable for human survival in the long run (Ćirković 2019). Reasons to go to space may be found in the so-called "ethics of life." Advocates claim that human life and survival constitute the highest value and priority, justifying and requiring that any and all attempts be made, including settling space or even bringing new life from Earth to space (Ketcham 2016).

Space ethicists discuss some metaethical issues. Depending on the preferred ethical position, ethicists argue either for or against space exploration and exploitation (Baum 2016). The debate on ethical and axiological values affects such issues as the rationale for human presence in space, the search for a space refuge, or the value of environmental protection and human survival. The issue of environmental protection is discussed mostly in relation to the putative status of hypothetical microbial life on Mars, and it includes mostly the ethical debate on the possible value of a microbial life and human right and duties towards any life in space (Cockell 2016; Wilks 2016; Smith 2016). One of the major ethical issues in astrobiology is the moral right to spread new microbial organisms elsewhere in space, and the right to favour terrestrial microbes over non-terrestrial ones (Milligan 2016a). Environmental ethical issues are involved even if no living forms are considered. Tony Milligan studies the ethics of mining of space bodies (Milligan 2016b). Another related issue is a human attitude toward exploitation of rare space resources. Schwartz discusses the case of the so-called near-Earth water sources. He argues that, due to their limited and non-renewable character, they may be exploited only for purposes such as conducting research or enhancing the survival of human species (Schwartz 2016; Schwartz and Milligan 2017). A similar issue is a moral right to terraform a planet. Advocates of this idea argue that there are good scientific, environmental, biological and anthropomorphic reasons to terraform Mars (Fogg 2011; Schwartz 2013), and terraforming is considered not only as morally permissible but even morally required (McKay 2011). Martyn J. Fogg rejects "preservationism," an ethical position which forbids the terraforming of Mars (Fogg 2000). One of the most common ethical supports for terraforming lies in an assumption that an inhabitable space is better than a non-life space, and humans, as self-conscious beings, have the right (sometimes even the duty) to populate space (Daly and Frodeman 2008). Jacob Haqq-Misra is an advocate of a more careful and conservative approach towards planetary engineering. He points out that two main concerns are the risk to the integrity of a microbial life, and the putative intrinsic value of the cosmos for humans (Haqq-Misra 2012). The issue of moral duty of planetary protection is rationalized by human presence in space (Macauley 2007).

An important group of ethical and legal studies refers to the issue of the future societal and political shape of the social organization on Mars, including the idea of liberating Mars from any earthly connotations, biases and rules, and an attempt to build a society of Martians instead of Earthlings (Haqq-Misra 2016). Similar arguments for establishing autonomous "Martian rights" are discussed by Robert Cowley (2019). Some scholars deal with issues on the intersection of the ethics of space missions, political philosophy, and political sciences, such as the possible political systems in space colonies (Cockell 2015a, 2015b) or the challenge of dissent, disobedience, and revolution in space settlements (Cockell 2016). Some philosophers discuss ethical challenges related to reproduction in space (Schwartz 2018; Szocik et al. 2018b).

A separate place in the ethics of space missions is occupied by the idea of looking for and meeting with the extraterrestrial intelligence. One of the discussed ethical issues is a concept of extraterrestrial altruism (Vakoch 2014). Another topic is the moral responsibility for appropriate contents sent into space, a possible optimal attitude to a hypothetical extraterrestrial intelligence (Vakoch 2011), and both benefits and drawbacks (mostly the unknown effects of a possible contact with extraterrestrial intelligence) of METI (Messaging Extraterrestrial Intelligence) attempts (Haqq-Misra et al. 2013). [Note 1].

It is worth noting that the idea of human enhancement for space missions, as discussed in our paper, has not been considered by space ethicists and philosophers. This is a new field in the ethics of space missions and space policy. However, some authors mention the idea of human modification, treated as an artificial, fast and controlled manner to adapt humans to a new and hostile space environment (York 2016, p. 63). Francesca Ferrando (2016) mentions the question of moral and legal rights to create a hybrid, i.e. a human being enhanced by DNA of a non-human animal species (known as interspecies enhancement or interspecies genetic engineering). She also enumerates some of the potential long-term consequences of human genetic engineering, such as the evolution of a new human species and any potential genetic preservation challenges. Last but not least, Milan Ćirković refers to the issue of post-biological evolution which may progress rapidly in the future, and which probably has already happened somewhere in the universe. These types of evolutionary changes may challenge a human system of values (Ćirković 2017).

In light of a literature review of the ethics of space missions, as outlined above, a conclusion can be formulated that no academic work released to date has discussed the idea of human enhancement for space in the same way as proposed in this paper. Some preliminary research in this field has been published by Konrad Szocik et al. (2019), Szocik and Wójtowicz (2019), and Szocik (2020, *in press*). The idea of human enhancement for space missions is definitely a new field within the broad framework of the ethics of space missions and space policy which is open to new arguments and further elaboration. Eventually, these discussions should filter into the development of space policy, and affect space programs in development, both governmental and private. It is noted that commercial (business) goals may affect the implementation of ethical standards, and, that this is yet another area for discussion as commercial space ventures emerge.

The Physical Context of a Mars Mission

The factors that stand out for humans in any lengthy spaceflight to Mars are confinement, monotony, movement in microgravity, space radiation, a need for exercise, distance from Earth, and the dryness of a completely artificially-generated air. There are several good, comprehensive examinations of the impact of these and related factors on human psychology during lengthy spaceflight (e.g., Kanas 2015).

There are similarities between Mars missions and other human expeditions of discovery, but the geophysical parameters of Mars are extremely different in terms of lower gravity (and its effects on human movement and gait), lower sunlight (and its effects on mood and loss of vitamin D), higher radiation (and therefore the constant need for protective clothing, habitations, and work spaces), incursive micro-particle dust (and its effects on breathing, hygiene, and daily habits), and a poisonous atmosphere (and therefore the need of a completely artificial and enclosed air supply). All these factors will operate *at the same time* to increase stress on humans. The planet Mars, itself, will impose restrictions on light availability, diurnal cycle, and human locomotion, travel, feeding, and waste management, which will immediately and almost constantly impact all members of a mission crew and all their interactions.

For these reasons, and in spite of the fact that some technical and medical solutions already exist (including human enhancements), a mission to Mars will be an opportunity to test the nature and flexibility of human moral systems and the emergence of new ethical solutions. Decisions will be needed on how to solve known physical problems and new ones, too. How careful will crew be required to be, in order to save their own and others' lives? Will the value of a human life be reduced or accentuated? Will "personal space" become even more highly valued, or will the concept disappear? Will leadership prevail or will its nature change? Will a new egalitarianism emerge and become entrenched, or will danger encourage authoritarianism?

For short-term Mars missions, these questions may arise but not require long-term solutions. For longer Mars missions involving settlement, conditions begin to approximate a deep-space mission in which a need for solutions introduces, in fact forces, a consideration of human enhancements, with their substantial moral and ethical challenges. How much change is too much change to the human mind and body? How many alterations to routine can the social organization of the crew withstand without rending? What level of known, not to mention unknown risk is acceptable for medications? For artificial limbs? For artificial lungs to replace human lungs damaged by Martian micro-particle dust? When does saving a colonist's life impose too much risk to other crew members and endanger the success of an expensive mission that is funded, at times, by competing organizations or inconsistent motives back on Earth? When is a high cost too much cost for the benefits of discovery, or, the profits of space mining? These are thorny questions without easy answers. Scenarios can be played out, but all the factors can never be anticipated. Both Mission Control and crew will need to be prepared for changes in perspective, including a context for "right" and "wrong."

Pushing the Ethics of the Human Body

The ethically challenging framework of a Mars mission will first be characterized. Then, selected technical fields are discussed that have a great potential to impact the human health and biology of Mars crew members. The fields of pharmacology, cyborgization, and genetics stand out as potential benefactors of a Mars mission, which have the potential for making a difficult mission, successful. At the same time, the application of these areas of technology contains a minefield of potential problems because they challenge our definitions of the human body, its normal functioning, its limits, and its potential for enhancement.

In pushing the human body to new limits, life on Mars will inevitably push human moral and ethical systems to new limits, too. The enhancements we address in this paper will challenge human values to an extent. When more intrusive changes are considered, the mind reels at the ethical questions. Let these remain, for a moment, within a Martian context. What if Martian dust is more damaging than we expect? Can we engineer the human genome and insert respiratory protections into the throats and lungs of all Martian settlers? Can we breed humans to tolerate Martian dust? With recent findings on talcum powder in mind (Berge 2018), will Martian dust cause ovarian cancer in female crew on Mars? If so, what interventions and enhancements are acceptable? Is the answer that humans not reproduce on Mars? If they do so, would it be better for the new Martians to be a different kind of human?

Human health and biology have always involved ethical questions [Note 2]. Medical interventions are vetted and their use either allowed or not by hospital and university Internal Review Boards. The question of human enhancements could be reviewed by some future Space Medicine Board. Experienced and sage reviewers would examine human enhancements, type by type, case by case if necessary, and reasonable decisions would be jointly made.

At the present, there are issues that can make a human mission to Mars very challenging from the long-term perspective of "colonization." Many of the current technologies for human space missions are barely more advanced than the 1960s, when the first human space flights and landing on the Moon occurred, and the 1970s, when the first space station, the Soviet Salyut, was launched. Throughout the ensuing 60 years, no space agency has sent human astronauts farther than to the Moon. The primary space activity for astronauts has been missions to orbital space stations. Even if technological capacities for longer human missions are developed in next decades, the social and political context on Earth may become less conducive to space missions because of climate change, population growth in some parts of the globe, population decline in other parts, and the world's limited ability to distribute human resources equitably, leaving enough to finance manned space missions. Ecological sustainability may become very challenging and it may re-focus the world populations on problems "at home" rather than on space missions to Mars. Therefore, Mars missions will gain substantial public support to the extent that they can be linked to activities or research benefitting all humanity. They will become more ethically tenable to people whose governments support space projects.

Intellectual and political justification of the costs of space exploration is a public discussion and a public relations campaign that have already begun, but still need far more investment. After the first excitement about space in the 1960s and 1970s, there was a long lull until the public became interested again in the early 2000s. Program planning remains tightly held in several large space agencies and private companies in developed countries, which have only in recent decades reached out to young and old alike to interest them in space travel and in Mars. At this point, it appears that the entrepreneurial side of program development may be starting to drive human space exploration as much as the political. There are differing ethical perspectives on this change, too, and growing concern that increasing competition in space will lead to war. Nevertheless, whether Mars missions are sponsored by governments or business, they will confront some of the same ethical questions about the human body – although their responses may be quite different.

Human Reproduction and Human Off-World Values

One of the biggest challenges in sending humans to space, to Earth's Moon, and to Mars may eventually result from the fact that human anatomy and physiology are not well suited for life in space without substantial protections. Humans are somewhat better suited for life on Mars because there is some gravity, but the suitability of Martian gravity for human gestation is still not known, and there are unknown risks linked to human reproduction in a Martian colony (Szocik and colleagues 2018b). If human reproduction on Mars is not possible, then plans for launching a long-term mission may require substitute plans to keep a community thriving and multi-generational. Concepts of a Martian colony have, to date, been based on a self-sustaining model in which humans establish a base that is independent of Earth. The colony would depend on natural replacement rather than migration from Earth.

To succeed, human communities usually require a potential for successive generations. However, it is possible to envision a Martian colony that is continually re-populated by waves of migrants from Earth, and these migrants could include children, to maintain a multi-generational Martian population. Still, this configuration substantially stretches the definition of "human community," which is defined by the *in situ* propagation of our species. To stray from this definition immediately requires a new type of social structure, and new values, norms, and customs that would be different from all other human communities documented by anthropologists (Whiteford and Friedl 1991). The ethical questions related to an alternative method for sustaining a community could require new roles, new customs, new values about procreation, reproduction, families, and children.

These remarks underscore the absence of medical and social knowledge of off-world human reproduction. Humans have been remarkably successful at reproducing in a wide variety of environments on Earth. There is a good chance they will succeed on Mars, but it may require health interventions that call forth thorny ethical questions, for example, the suitability of an "artificial womb." Still, medical technologies to keep very premature infants alive is inching ever closer to the technology for an artificial womb. The two capacities may eventually merge. Questions about the effects of specific aspects of the Martian environment, such as low light, lower gravity, atmospheric density, dust, radiation, and the human requirements for breathing, feeding, and watering will all eventually impact human reproduction. Yet, it is not known how human reproductive biology will be affected by these factors. At the present, it appears that the greatest danger is radiation (Szocik et al. 2018b; Santy and Jennings 1992), and to a lesser extent, microgravity and reduced gravity (Sasaki and colleagues 2004). At this early stage of planning, it remains difficult to envision a permanent settlement without some means to form future generations of Martians.

Furthermore, events may outpace all of these questions, if and when humans are conceived and born during spaceflight.

Moral and ethical standards about human reproduction may need to be modified in comparison to cultures on Earth, some of which espouse no contraception. In space agencies in the West, there is an informal, growing conclusion that the first Martian crews should all practice contraception. This may lead to omitting crew who are to unwilling to practice contraception. Nevertheless, no contraceptive technology works one hundred percent the time. When pregnancy ensues during spaceflight or on Mars, what are the options?

Without clear knowledge of the safety of pregnancy in conditions of microgravity or lower gravity, abortion may be difficult to support or justify. On the other hand, what is the greater risk?--Abortion or birth of an infant on the way to Mars? Countervailing questions present themselves: Is it morally just to prevent humans from being born off-world or on Mars? If it is not at first biologically possible for humans to reproduce in the Martian environment, or in an off-world environment generally, is it possible to imagine special modifications of the human genome to achieve fertility? Or to prevent fertility? These scenarios have heretofore taken us far into the future. However, in a sense, tomorrow has arrived and the issues surrounding human reproduction need to be anticipated, vetted, and contraceptive technologies provided to crew and early colony members who want them. Above all, a discussion on the ethics of the options needs to be broadened and intensified, and the crew who cannot justify their own use of contraception can be forewarned and can choose not to participate.

It is possible that early Martian crew may submit themselves to sterilization, in case the trip involves a radiation storm, or even if individual crew feel that the risk of receiving a radiation dose on the round trip is more than they can personally tolerate. They may wish to store eggs or sperm on Earth, which is an approach already taken by individuals who receive radiation in medical treatment on Earth. Once on Mars, the dangers of radiation are reduced somewhat, but without protective gear, habitations, and protocols, radiation remains a danger for future human reproduction on Mars, and for human activities, in general.

How will this danger be met? At the outer limits of planning scenarios, genetic intervention in candidates for future Mars missions should be considered. This could mean purposefully altering genes of pre-launch crew (Szocik 2015; Szocik et al. 2019), just as in the case of human reproduction. This danger is worth serious consideration because current anti-radiation countermeasures are insufficient (Vico and Hargens 2018). Solutions include enhancing immune and musculoskeletal systems (Szocik et al. 2019), and application of regenerative medicine (Cortese et al. 2018). It is also possible to insert some genes into humans which may enhance radiation resistance (Klompe and Sternberg 2018).

What are the ethical repercussions of the countermeasures to confront high levels of radiation, both for humans on Mars and humans who remain on Earth? Changes in ethical standards in one location will necessarily affect them elsewhere, because humans communicate endlessly, with everyone, all the time. Humans are a talkative species. This "backflow" of information and standards is an issue rarely addressed, because humans conceive of Earth as changing Mars. However, Mars will change Earth, too. Planning for this change is a powerful reason for considering the issues of ethics and human biology now.

Unique Conditions and New Ethical Calculations

Conditions in a Martian base will be extremely different from all environments on Earth. In the following discussion, it is important to identify key differences and ask if physical and environmental factors call for differences at the levels of values, norms, customs, and ethics. Further study questions arise throughout a discussion of how these factors might function. How will life on Mars change values concerning the human body and its biology? These questions will be important for social scientists as well as physicians because human organization and culture change regularly according to both internal and external forces, some of which are known. What is not known is whether and how they will operate on Mars, and which new forces might emerge from within the crew or imposed from the external environment.

Human missions to Mars are not simply repetitions of previous terrestrial challenges of threatening territories, extreme environments, and limited resources. Leaving Earth and travelling to another planet is a new experience for human psychology and physiology. Awareness of being sent beyond Earth to another planet is made even more acute by knowledge of the risks and the many stressors studied in space psychology (cf. Beven 2012). If Mars becomes the place where human enhancements become routine, there will be stages of decision making that take each one from an innovation, to a good idea, to perhaps a necessity. Space ethicists and physicians should ask if the risk of sending astronauts *without* enhancements and exposing them to unnecessary danger is, itself, ethical. Risks, benefits, and costs will have to be carefully weighed. Mars will be different in ways that will require new ethical calculations. It will eventually encompass a permanent colony in a difficult environment based always and completely on a reliable life support system. By itself, that is daunting. There will be no "time out" from a need for oxygen to breathe. No timely evacuation or help from Earth will be available.

Planetary Environment and Ethics

Some physical differences between the third and fourth planets from the sun include atmosphere, ambient radiation, and temperature, just to name a few. The Martian atmosphere is much thinner than Earth's atmosphere, and it consists of almost 96 percent of carbon dioxide, argon, and nitrogen. The surface pressure on Mars is six-thousandths of Earth's atmospheric pressure (Weintraub 2018, 107). The absolute concentration of carbon dioxide is very low, too low to cause a greenhouse effect for terraforming. Recent estimates are that the Martian carbon dioxide extracted from all possible sources offers only 6.9 percent of the total amount of gases required for an Earth-like greenhouse effect (Jakosky and Edwards 2018). Oxygen is about 0.15 percent of the atmosphere. The thin atmosphere is not able to inhibit sunlight from heating the surface. Consequently, the temperature near the ground may be 75 degrees Fahrenheit, but only 32 degrees two meters higher (Solar System 2018).

Due to the thin atmosphere, Mars is exposed to asteroids. The Martian atmosphere does not cause enough friction to burn up asteroids coming toward the planet. Mars lost its atmosphere billions of years ago, along with its ability to sustain life (unless sub-regolith microbes are discovered, which is still a possibility). Loss of its atmosphere also caused a loss of surface water. It is estimated that pH-neutral water existed on Mars about 4 billion years ago (Witze 2014). However, water is still available both as a component of the polar ice caps on Mars and as a liquid lake about 0.93 miles below the surface of the South Pole (Orosei et al. 2018). The surface of Mars is affected by cycles of dust storms lasting as much as several months, and sometimes as long as a year. Dust may encircle the entire planet and decrease the temperature by inhibiting sunlight (NASA 2018a). The Martian gravity is about $3.71 m/s^2$, or about 38 percent of Earth gravity ($9.8 m/s^2$) (NASA 2017a). The thin Martian atmosphere and the absence of a magnetosphere together offer little protection from cosmic radiation, including solar particle events (SPEs) and galactic cosmic rays (GCRs). A radiation dose on the surface of Mars is similar to that on the ISS (Simonsen and Zeitlin 2017).

In practical terms, the total radiation exposure on Mars will be, at minimum, six times higher than the International Space Station exposure because ISS missions last only six months (producing a 160 mSv radiation dose), while the shortest mission to Mars is three years (producing a 1,200 mSv radiation dose). Radiation will be 105 times higher than during the nine-day Apollo 14 lunar mission (Rask and colleagues 2008). Crew who served on many ISS missions absorbed about one-third of the expected Mars radiation dose (Simonsen and Zeitlin 2017). The radiation dose on the ISS is about ten times higher than on Earth (Abadie et al. 2015). These differences in radiation exposure will prevent any ability of maintaining human life as it is known on Mars, without suitably protected habitations and protective suits. This fact could make living on Mars extremely difficult for human psychological health and call forth new rules for group living.

Other differences are caused by geological and atmospheric conditions. Among them are limited sources of light, the difficulties of extracting frozen water from ice caps or mining liquid water that is stored deeply under the Martian surface, and the distant challenge of farming the Martian regolith, which may be possible, but will be difficult. The Martian regolith is sterile, with no bacteria or fungi that we know of yet. There is also toxic perchlorate in regolith (Davila et al. 2013; Wamelink et al. 2014; Ming 2016; Heiney 2017). It is hoped that these problems can be solved with new technologies, but until that time, humans will survive on food brought from Earth or farmed in greenhouses on Mars, which have a variety of configurations. Various schemes have been designed to "terraform" the Martian regolith by seeding it with lichen and bacteria, but implementation of this type of technology is untested and probably far in the future.

Comparisons have been made between Martian colonization and some difficult human expeditions to earthly environments with extreme conditions like Antarctica, although the analogies have their limitations. The psychological experiences of Antarctic expeditions and the lengthy stays there appear quite similar to those described by the ISS astronauts (*cf* Zimmer et al. 2013; Smith et al. 2017). Some small human populations who have adapted to extreme conditions, like North American Eskimo, provide previews of the challenges that crew or colonists might face on Mars, where humans could not receive any immediate external support. A Martian colony is alone in a way unlike any earthbound human population has ever been alone. Service at the ISS is a case in which life is constricted, but there is an opportunity for a fast extraction on board two Soyuz spacecraft permanently attached to the ISS, in case of emergency. In a similar situation on Mars, the windows when the crew could return to Earth are very restricted. There are various scenarios of powering an ascent vehicle by extracting propellant from the Martian atmosphere in the form of diatomic oxygen, but preparing it as liquid fuel will require the crew to have additional, advanced technologies. There is an added incentive for developing these technologies, however, since liquid fuel can become a valuable commodity for missions further out in the solar system.

The existential fact of Martian isolation may create conditions that are exhausting for the human psyche and emotions. Decision making by the crew – including ethical decision making – may be impacted. Reactions may run the gamut foreshadowed on Earth by depression and "failure to thrive," and anxiety conditions will run from claustrophobia to agoraphobia. Psychiatric disorders may range to conditions newly identified by psychiatrist Nick Kanas (2014). Humans will be for the first time in the history of their species in a situation where their life depends *all the time* on a technical life support system and their ability to keep it running. Rescue procedures will have to be practiced over and over, and over again, reminding everyone of how close to the edge of existence they live. Enclosed living in small groups in a Martian colony may be reassuring at times, but it may also be extremely demanding socially, culturally, and ethically. Methods for releasing tension will be limited. New forms of personal and group decision making may take shape to manage conflicts unknown on Earth. A variety of psychological problems can be addressed with the careful use of pharmacological aids to assist the crew in adjusting to difficult conditions. Their use is inevitable on journeys to Mars, but the protocols for using them have not yet been fully developed for these circumstances. Careful view by Internal Review Boards or a Space Medicine Board would be an integral part of mission planning.

Whereas daytime temperatures on Mars may be close to those on Earth, reaching 68 degrees Fahrenheit, at night temperatures often fall to minus 307 degrees. According to Robert Zubrin (1996), participants in the first human missions to Mars will have to depend fully on themselves. He envisioned that colonists would do the following: Build a brick settlement using furnaces brought from Earth; manufacture plastic materials from carbon and hydrogen; make glass and ceramic materials; and search for needed water resources (1996, 174-175). More recently, and perhaps with a sharper eye on cost and practicality, a wide variety of modular, prefabricated, and inflatable designs for habitation, greenhouse, and laboratory facilities have been conceived (e.g., NASA 2017b). New information technologies could furnish these designs with landscapes, views of the Martian surface, and peaceful scenes that make the habitations more liveable, thus reducing stress.

Human Enhancements in an Ethical Context

Life in a constantly dangerous Martian environment requires modification of an approach toward life for future astronauts and the public that supports them. It will be necessary for mission success and to maximize the chances for crew survival. A program of human enhancement for many, if not for most, of the crew will include genetic modification and strong pharmacological support, which are interventions that could well be ethically controversial and difficult for the public to support. We do not refer only to palliative care, but enhancements that improve work performance and extend the tolerance of the human body in order to withstand spaceflight, and life and work on the Martian surface. Häggström (2016) gives an overview of counterbalancing factors that should be considered in any ethical approach to human enhancements. Will they cause as much good as harm to human anatomy and physiology? Will human autonomy, individuality, and liberty – and we would add, initiative and motivation – be challenged by invasive drugs and measures that allow humans to survive the rigors of spaceflight and work on the surface of Mars? Do space programs risk accusations of exploitation in implementing human enhancement programs? These are all serious issues that a public whose tax monies support space programs will eventually confront. Program decisions that run counter to many people's social, religious, and political values may be challenged.

Questions arise concerning the extent that mission planners and public opinion will accept a need for radical modification and interference with "human nature," psychology, and anatomy. Values vary by culture, but there has always been a limit to interference in every culture. That said, cultural evolution and socioeconomic development have gradually led to an acceptance of modification after modification, and incorporated them into human anatomy, functioning, and culture. For example, ancient Egyptians used dung plugs as IUDs for contraception. Modern western cultures accept IUDs as a relatively safe form of contraception; they prevent implantation of a fetus in the wall of the uterus. Some tribal Native Americans of the Brazilian rain forest simply jump up and down on a pregnant woman's belly to effect an abortion. Modern western cultures use more humane pharmacological and surgical procedures to effect abortion. Human cultures approach the control of their level of population with a wide variety of means, including the very long Australian aborigine post-partum sex taboo of 5-6 years. Values surrounding the use of all of these "technologies" and customs, and others, vary widely, and many people in modern societies maintain opposition to them, even if they are legally prescribed. At some level, as part of either overt or covert culture, they achieve a level of acceptance among individual cultural groups and become enhanced with positive values. Human reproductive anatomy remains today the object of many "medical" and "religious" modifications, such as, in East Africa, infibulation of young girls, and in the West, circumcision of males as infants, or, in the Middle East, circumcision of teen Islamic males. All of these innovations are cultural, not biological. They are sometimes labeled "medical," although their palliative nature has often been questioned by modern medicine. Some are accepted by major religious traditions, and some are not.

How far humans have come in their acceptance of modifications is evident even in one of the co-author's new optical implants following cataract surgery (together providing 20/20 vision), which came complete with two formal identification cards if a retinal scan is ever questioned. Pins holding together human spines and arms are routinely encountered at airport security. Pacemakers, artificial limbs, Bluetooth hearing devices are all now routine, as are heart and lung transplants. Medications to tolerate the anxiety of medical exams are equally routine. Gene therapies have saved a former US President's life, and now others' lives. The steps toward human enhancements and genetic modifications to aid Martian crews are not very far behind because they are already used on Earth.

The current literatures in ethics, philosophy, and law do not discuss the challenge of human enhancement and survival in space. Nevertheless, some issues confronted on Earth will naturally apply to human space missions, as well. This parallel, however, is neither clear nor simple. Some criticisms of human enhancements will remain, based on, for example, the issue of equality of access to technologies, or the unpredictable consequences of implemented changes, or sensitivities about altering so-called "natural" bodies, which often already have enhancements. More broadly, in the context of deep-space missions, the therapy/enhancement distinction is even now being called into question. The demarcation between procedures designed to improve human health and the ability to recover from disease are usually accepted as non-controversial. The procedures designed to enhance the performance and capabilities of healthy human beings remain at the core of the ethical debate. The emerging philosophy of human enhancement in space holds that astronauts should be allowed to increase their adaptive capacity for living in a space environment because it is such a challenging one. In this context, human enhancement is not treated as an extravagance without a pragmatic rationale, but as a necessity justified by both humane concerns and practical, biological requirements.

Future astronauts might be enhanced at least in two dimensions. One of these is the application of new, prosthetic or genetically engineered capabilities which are designed for living in a specific space environment, such as living in a microgravitational environment. Another dimension involves earthly capabilities, such as cognitive enhancements (Melo-Martin 2010, 484; Menuz 2013). In the latter case, cognitive enhancements may not be essential for astronauts, but they might be considered rational and optimal tools to maximize the efficiency of space missions.

The moral and legal right to enhancement is discussed in terms of a duty by, among others, Ingmar Persson and Julian Savulescu (2017b).[1] They write that humans may be viewed as morally obliged to do everything they can to increase the chances of fulfilling their moral duties. They hold that the obligation to perform morally right acts may not only justify, but even imply, the need for enhancing moral capacities like so-called "altruism" and a sense of justice. On the other hand, biomedical moral enhancement (BME) is considered an obligatory means of increasing the human ability to care for the common welfare (Persson and Savulescu 2017a).

A cautionary note should be sounded that these authors have perhaps confounded a moral obligation to do everything possible to save crewmates, with a moral obligation to incorporate advanced biomedical devices or drugs that are, to date, not proved safe. The state of knowledge of pharmacological or genetic support for "morality" is not in a sufficiently advanced state now to give humans a reasonable choice about biomedical remedies for some lack of "morality." The view of Persson and Savulescu is that the main rationale behind "moral enhancement" is the incompatibility between technological progress, on the one hand, and the narrow set of human moral intuitions which evolved in a previous environment, on the other (Persson and Savulescu 2015, 48). New technological solutions challenge human morality because they open space for new, previously unavailable and even unimaginable, procedures. Again, a cautionary note is suggested by their model, because while opportunities are given by new technologies, they usually come with problems and conflicts, too; the ethnographic literature is replete with examples, as are the files of international aid organizations. Persson and Savulescu (2017b) argue that, if traditional moral education seems ineffective, moral enhancement could work as a supplement. In their view, moral bioenhancement is treated as a hypothetical obligatory tool to ensure the survival of mankind.

[1] See also the last discussion in *Bioethics* special issue on germline gene editing at https://onlinelibrary.wiley.com/toc/14678519/0/0.

The issue of granting an informed consent, and the risk of such a consent for enhancement procedures, could be justified in some socially reasonable situations, as in current law and social policy (Persson and Savulescu 2017b). Nevertheless, this could be seen as an extreme option that does not, itself, provide sufficient informed consent to any potential Martian crew, because there is not enough known about the risks or the benefits. It becomes a non-choice. Pharmacologic or genetic tinkering with human moral capacity does appear at first glance to be sacrificing too much humanity for the sake of too little. It would not be the human species colonizing Mars, but a different version of the human species. That decision is probably still far in the future, although a search for options in artificial intelligence development has already suggested mechanisms for programming moral decision making (Rappaport and Corbally 2020). Comparable technology may eventually be available for humans, cyborgs, and machines.

A human mission to Mars, and possibly Mars colonization, might cause a new challenge for the therapy/enhancement distinction, as discussed above (cf Bostrom and Roache 2008). The key idea of this distinction assumes that enhancement, in general, is not oriented towards therapeutic issues and, as such, is applied only to healthy individuals. Future Mars astronauts will be individuals in the best of health. However, the context of a space environment and the need for adaptation to life in space may give rise to new situations in which the use of an enhancement in astronauts may be treated as a kind of therapy. The implication is that enhanced astronauts, who get new capacities to normally function in a new environment, correspond with equivalence to unenhanced humans living on Earth.

One of the principal reasons for differences in the ethics associated with human enhancements on Earth, and during Mars space missions, is that a human enhancement on Earth is usually an option – a human choice. Aims are achieved using generally standard methods. In the case of a human mission to Mars, the border between an optional enhancement and an obligatory therapy becomes blurred, and the choices are no longer as clear as they were on Earth. The distributive justice objections concerning inequality and unfairness, as well as loss of human autonomy caused potentially by human enhancements on Earth, lose their critical power in relation to space missions. Even scholars who are in favor of enhancements, recognize many of these issues (Giubilini and Sanyal 2015, 233). In these authors' view, which accepts enhancements to increase human welfare and "the good life", offers a support for human enhancements designed for deep-space missions (Giubilini and Sanyal 2015, 234). Space missions are recognized for the danger they represent.

Counterarguments discussed by some followers of a restrictive approach to human enhancement do not always apply to human spaceflight [Note 3]. However, "conservationists," i.e. people who reject any form of human enhancement, offer arguments which may be applied equally to Earth and space. They invoke the putative risk to human dignity and human nature, or the metaphor of "playing God" (Giubilini and Sanyal 2015, 239-240), which is impossible, so the metaphor collapses.

An especially important issue in the ethical debate on human enhancements is the validity of the risk-benefit analysis, partly because it involves value judgments about both risks and benefits, within a policy and program context. Inmaculada de Melo-Martin (2010) is critical of risk-benefit because she suggests there is a methodological problem when the risk-benefit analysis shows more benefits than risks. In that case, it is difficult to offer strong counter-arguments to the application of a human enhancement (Melo-Martin 2010, 485). She argues for an approach that goes beyond risk-benefit analysis and identify specific goals, and then to check if a given goal – if assessed as valuable – may be achieved with non-enhancement procedures (Melo-Martin 2010, 486-487). As a cautionary note, it should be emphasized here that Melo-Martin's methodological take on risk-benefit analysis may be limited by an existing prejudgment against enhancements, or by inadequate preparation. The definition of the values upon which a risk-benefit analysis is based must be sufficiently robust to offer a range of results in practical application. The determination of a repeated excess of benefits in a variety of analyses should be approached with care, and would suggest that the original analytical framework was not sufficiently comprehensive to assess a variety of options. In that case, results could well be spurious, and the values assessments embedded in the analytical framework would require re-evaluation and re-definition for further application. In other words, if a risk-benefit methodology is properly prepared, it should be able to handle a large variety of similar program cases.

The ethical evaluation of human enhancement procedures is context-dependent, and it may be program-dependent, society-dependent, and/or culture dependent. Part of the methodological development of risk-benefit is to clearly state these contextual influences. If a particular group includes only enhanced members, there is no risk of any unfair competition between the enhanced and unenhanced individuals (Allhoff *et al*., 2010). There are possible scenarios in which representatives of certain professions might be considered candidates for some enhancement procedures, for instance, soldiers or pilots of aircraft who should display a high level of physical performance and skill (Allhoff *et al*. 2010). Application of human enhancements should be viewed as an option in cases where the specific character of a given profession, targeted at specific tasks, requires highly specialized skills and capabilities that cannot be developed and exercised with standard means (or if they are too burdensome). There are some premises that justify viewing a human mission to Mars as encouraging or even requiring human enhancement procedures. It is an argument that may become more widespread in the future.

Some ethical objections are formulated in connection with gene editing procedures intended to modify germline cells, rather than somatic cells. The main ethical issues tend to focus on such questions as the risk of social inequality, the risk (or the advantage) of passing genetic modifications to next generations, and the use of gene editing procedures for some arbitrary or frivolous purpose of human enjoyment, beauty, or gain, rather than for therapeutic indications (Gallo *et al*. 2018). These objections are not applicable to human space missions as long as the procedure of gene editing is considered only in terms of somatic, not germline, cells.

However, some ethical approaches show that it may be logically difficult to formulate objections against human enhancement procedures. For example, following the no-harm principle, human enhancement would be permitted as long as it does not harm any human being. Another example follows the subjectivist approach in ethical theory, stating that there are no objective principles that should be shared and accepted by all members of a pluralistic society (Roduit *et al*. 2015, 625). Neither of these arguments is spurious, but their relevance to survival on Mars may become tenuous.

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Enhancement should not be automatically, without review, prohibited by any responsible space medicine board. Instead, it should be treated as an option that merits careful consideration. This idea has been discussed by Nick Bostrom and Julian Savulescu (2008) who argue that enhancement should be normalized. This implies that enhancement should not be prohibited, but every option should be carefully evaluated, and then permitted or prohibited. Some human enhancements have been referred to as a "radical" human enhancement, although caution should be taken in using a term that carries any inherent negativity and whose definition may change substantially in the out-years. Now, Melo-Martin defines a "radical" enhancement as one that involves the development and application of capabilities that are not possessed by any human being (2010, 484). When applied to astronauts, these may include solutions for coping with a space environment, including high radiation or reduced gravity. It is difficult to apply the term "radical" to prostheses of the usual orthopedic sort or newer augmentations from genetic engineering. These enhancements are capable of preventing severe radiation poisoning, or cognitive and physical disorientation from weightlessness. They are able to save astronauts' lives, and if thoroughly tested, should be used to help them achieve mission goals. It is a humane choice.

If the evaluation of enhancement procedures is a reasonable course, then the type of intervention, itself, should not be cloaked in ethical controversy. More specifically, if a given enhancement procedure leads to some capability that is necessary for human astronauts to survive in space, then an enhancement should be evaluated by at least two criteria. First, will the enhancement be necessary to survive and, possibly to complete specific tasks for purposes of the mission? This criterion has important consequences because it suggests that some kinds of enhancement not intended for survival should be prohibited. Second, will the enhancement provide a function that cannot be achieved by other means

The issue arises as to whether living in microgravity during a long spaceflight, and then in reduced gravity on Mars, provides a justification for human enhancement – if we assume there is an enhancement procedure that makes astronauts immune to the harmful effects of modified gravity. Artificial gravity is an alternative which is currently beyond human technological capabilities. Relevant public policy should contain a clear set of standards and procedures, including cost/benefit and risk/benefit analyses. Laws and regulations should clearly explain the financial limits connected with both enhancement and non-enhancement options. Costs and risks must be weighed against human benefits, both tangible and intangible, and both long-term and short-term. When a human enhancement appears much cheaper than the non-enhancement alternative, mission planners should, finally, consider public response before making decisions.

A technological implementation called "brain-computer interface" (BCI) may be a complex and controversial type of human enhancement for a Mars mission that involves additional factors beyond the criteria described above. BCI solutions may create threats to human privacy or the risk of discrimination (Yuste *et al*. 2017, 161-162). On the other hand, some authors argue that cognitive enhancement may lead to reaching desirable properties that increase human autonomy (Schaefer *et al*. 2014, 135). This way of thinking may seem counterintuitive because human enhancement procedures are usually viewed as a threat to human autonomy. Nonetheless, G. Owen Schaefer *et al*. argue that human beings with enhanced cognitive capacities become equipped with extra skills which give them *more* autonomy. Even when one agrees that BCI does not challenge human autonomy, it will be necessary to evaluate just how necessary it is for space missions. The future contains many unknowns. Research may discover that it is necessary for survival or for the efficiency of crew's performance.

Early Targets for Enhancements: Bone Loss, Radiation, and Other Health Dangers

While NASA's training program is able to reduce bone and muscle deterioration in microgravity, for example on the ISS, lack of regular physical exercise is expected to cause a 50 percent loss of muscle strength during a three-year Mars mission (Gaffney et al. 2017). During a six-month flight to Mars, astronauts will be exposed to a variety of dangers – absence of gravity, isolation, disease, injury, and space radiation – all of which will be compounded by a lack of access to Earth's resources. All of these dangers will be made worse by diminishing bone and muscle strength. According to NASA observations, bones lose minerals without gravity pulling on the body, and their density drops over one percent per month. By comparison, the rate of bone loss for elderly men and women on Earth is 1 - 1.5 percent per year. Confinement to an enclosed space for a long period of time will increase human stress hormones, producing weakness and exposing astronauts to diseases such as the Epstein-Barr virus.

Radiation is one of the largest risks for human physiology in space, and it is being studied carefully before human missions to Mars (Zeitlin et al. 2013; Cucinotta 2015; Cucinotta et al. 2015). Mars rover Curiosity reported that it received, during its almost nine-month journey to Mars, a rate of radiation equivalent to the amount of radiation absorbed during 90 years of living on Earth (Barker and Gilroy 2017). Risk of cancer increases substantially during cumulative ISS missions or missions longer than 18 months (Cucinotta 2014). Radiation affects reproduction (Wickman 2006) and causes many deleterious health effects in addition to cancer, for example, central nervous system harm and tissue degeneration (Cucinotta and Cacao 2017; NASA 2018b). Space radiation negatively affects the human neuronal system, decreases cognitive performance, and affects decision-making processes (Alp et. al. 2015; Parihar et al. 2016).

In addition to microgravity, reduced gravity, and space radiation, NASA describes health risks caused by the space environment, including, "risk of adverse health and performance effects of celestial dust exposure, risk of adverse health outcomes and decrements in performance due to inflight medical conditions, risk of bone fracture due to spaceflight-induced changes to bone, risk of ineffective or toxic medications due to long term storage, and risk of renal stone formation" (Institute of Medicine 2008). While they are not perfectly analogous, NASA uses underwater conditions to train for a space environment and to test medical solutions (Piantadosi 2015; NASA 2018c).

This is all necessary information for Martian crew members during their years of selection and training, which would, of necessity, address the possibility of burial or other disposition such as composting, freezing and preserving of an astronaut's remains on the Martian surface or during the long spaceflight, to and from Mars.

Formation of Martian Society and Its Difference from Earth

The creation and initial stages of a human settlement on Mars may affect the long-term development of Martian society for years, so it is important that it proceed well and that responsible measures be taken to encourage good health, good government, and adequate planning. Formation of Martian society may resemble, in some ways, the emergence of societies on Earth. The expansion of a Martian settlement and the arrival of new settlers may lead to the situation in which some humans feel more Martian than Earthling. The identities of newcomers gradually change after their resettlement. This is a process that has been repeated time and again, while humans settled and re-settled new areas on Earth.

One of the factors potentially differentiating Martians from Earthlings will be genetic modifications and cyborg upgrades for crew or settlers. Indeed, cyborg upgrades may be incorporated into the recruitment of new crew and/or settlers. Earth-based ethical systems usually refer to humans who are similar to each other physiologically and psychologically. In general, they are "non-modified humans," although much work needs to be done to define this term well and integrate it into human enhancement and cyborg protocols for the future, on Earth, Mars, or elsewhere.

"Cyborgs" can be defined as substantially modified humans who possess other, or improved capacities compared to non-modified individuals. When the first human cyborgs appear, either on Earth or on Mars, they may introduce new behavioural norms. Indeed, there is a substantial likelihood that they may first appear in armed forces on Earth or on its Moon. The potential for substantial cyborgization of Mars crew members could include surgical techniques that improve human performance in an extreme environment. While this may sound like "science fiction," we believe that by the time Mars is settled, human cyborg enhancements will be available, in some cases be desirable, and in some cases even be required for certain types of off-world work. The discussion about the ethics of their availability, desirability, need, and the behavioural guidelines for their integration with non-modified humans needs to start now.

Cyborg enhancements may emerge naturally from the need for humans to operate in a difficult space or Martian environment, and from possible militarization of space settlement. A simple, although in many ways, sad analogy is the use of Army troops on horseback that accompanied settlers to the American West. If competition and war emerge from the colonization of Earth's Moon, it may spread to Mars, or, at least cause the settlement of Mars to involve military troops. The ethics of cyborg enhancements within the military will be addressed differently by various nations and geo-political groups, and looser ethical standards may prevail for soldiers than they do for civilians. This is true even now. The priorities of mission success may affect ethical consensus, both for the public and for the military, and the western values on an individual human life, and on justice and freedom may be modified [Note 4]. With this possible eventuality, the discussions need to begin now.

Currently, the US military and its contractors conduct research on various applications of cyborgization. Research topics include personnel management during recruitment (using brain imaging technologies), efficiency and tiredness management (enhancing humans with a hardened and "smart" exoskeleton), disability management (bionic limb prosthesis, after injury, increasing the opportunities for trained personnel to remain at their posts), and cognitive capacities management (brain stimulation for improved assessment and decision making). DARPA (Defense Advanced Research Projects Agency) is working on nanosensors designed to monitor life functions of soldiers and to detect diseases. As soon as they are deployed, this type of solution could be useful for American soldiers who operate in remote areas (Castro 2012), and potentially, astronauts on the Moon, in spaceflight, and on Mars.

A Mars mission will necessarily involve human integration with machines to monitor bodily functions of crew members and to manage colony organizational functions for convenience and safety. Robots will be especially useful in all situations requiring extra-habitat activity, when human astronauts would be exposed to space radiation or deeply affected by invasive Martian dust. When the appropriate protocols have been developed and vetted, human genetic engineering will also be used not only to ensure and enhance the health of crew members, but to extend their physical limitations in a new and very different environment whose constraints can only be imagined and partially tested here on Earth. Humans on Mars may represent a new kind of human, in many real senses, and it is these individuals who will collectively provide changed parameters for a new type of society and social structure. At first, it may seem little different from earthly societies, but as time goes on, social, cultural, and ethical conventions will evolve, be tested by colonists, and be used and retained. These same individuals will consider, vet, and discard some conventions that originated in Earth's societies.

Again, the discussion of these future developments needs to begin now, because all humanity has a stake in them. As noted previously, there will be "backflow" of changed values to Earth, comparisons will emerge, and there will be both consensus and conflict when it comes to decisions about "right" and "wrong."

Social Cohesion, Enhancement Programs, and Ethics

Every human community is organized according to rules, and human biological needs are at the base of many. The result is generally cooperative, human social activities. Still, there remains a tension between individual and social goals.

It can be assumed that early Martian bases and settlements will face an extremely difficult environment, in which former crew members will be constantly vigilant to a variety of interacting, external stressors of a very basic nature (gravity, atmosphere, radiation, low light, and dust). The challenge will be to enhance social cohesion and maximize cooperation in early Martian colonies. While space settlement should be fundamentally a cooperative activity, we cannot exclude emergence and impact of disharmony (e.g., Cockell 2016, on the risk of exploitation and tyranny in a hypothetical Martian government).

Humans who are in confined Martian habitats, constantly dependent on life support systems and the distribution of what will be limited resources, may be exceptionally prone to be exploited by leaders of a Martian base. The lack or limitation of emigration and escape may introduce an extra risk for the early Martian population. When the long-term scenario of a Mars base is developed, mission designers should take into account this specific ethical issue – the risk of exploitation and authoritarian management or "rule." The likelihood for this dangerous scenario will hinge on the cultures of the crew and early inhabitants, and on training to avoid injustice, inequity, and lack of due process.

Concluding Remarks

Our analysis of possible risks and challenges associated with the special conditions of travel to Mars and life on it, suggests that the Martian environment will require future mission planners and future colonists to re-consider and possibly modify ethical standards and longstanding moral precepts that emerged in Earth-based societies. There is no doubt that human life will be endangered on Mars and on the journey to it. Space exploration will be dangerous voyages of discovery. The idea of implementing human enhancements is considered here as a possible ethical issue that may appear in the near future, and which may challenge our moral and ethical intuitions.

The question is how, and to what extent the value of human life, and its independence and free will, are going to be challenged during the spaceflight to Mars and in the Martian environment. Enhanced astronauts may be better adapted to hazardous factors in space but the question arises if mission planners should apply any radical enhancement procedures that may affect human freedom and autonomy. Enhancements may be especially challenging if they are irreversible and are applied to astronauts who are going to return to Earth after their mission in space. There will surely not be a uniformity of opinion among the Martian crew or colonists. On Earth today, there is no universal set of human moral values, although they all address a very basic set of human needs that characterize the human species. Ethical challenges are different from culture to culture, and society to society.

We close our review of challenging and perhaps disquieting new technologies for human application by reminding the reader that off-world colonization may cause fundamental changes in human moral and ethical standards, especially when colonists are confronted with extraordinary dangers and challenges to human cooperation that they never envisioned. The biggest challenge for human cooperation on Mars will be permanent dependence on a life support system, dependence on delivery from Earth, and no possibility for evacuation or escape. Of the external physical stressors on the planet, we have highlighted the special dangers of radiation and lower gravity, but we also see the potential dangers of Martian rock dust to carry perhaps just as much danger for humans.

Indeed, it may be that in a Martian colony, some individuals will be ready to change the ethical and moral standards they knew on Earth in order to survive in a new environment. Other crew may not be so willing. As a consequence, mission success may be endangered by dissension, decreasing morale, and physical disease and injury. Novels have been written about individuals willing to take risks to secure their place on other planets. The question will be whether humans are able to accept the costs and risks associated with changes in moral and ethical standards during a Mars mission. A question on human enhancement for space is, in fact, a question on the rationale for sending humans to a deep-space environment. Is there a sufficiently strong reason to go to space which justifies the enhancement of future astronauts?

Note 1. Space ethics still attracts philosophers' and scientists' attention. In 2019, two academic journals that are not generally devoted either to space or purely ethical considerations, i.e. *Theology and Science* and *Futures,* published two special issues on the ethics of space missions – in fact, on ethical issues of a mission to Mars. Contributions to the special issue published in *Theology and Science,* entitled "To Mars, the Milky Way and

Beyond: Science, Theology and Ethics Look at Space Exploration," discuss such topics as the ethical consequences of access to resources on Mars, and to the possible traces of life, for future Martian settlement plans (McKay 2019). They also address a human right to colonise space (Hart 2019), the duty to colonise and terraform Mars, as a duty towards human nature (Zubrin 2019), and an exactly opposite ethical position – a human duty to stay on Earth, to care for it and to find a meaning in being Earthlings (Newell 2019).

The *Futures* special issue entitled "Human Colonization of Other Worlds" is devoted to ethical issues on the human right and rationale to colonize space. Contributors discuss mostly human rights to colonize space in the context of various ethical, cultural, political and social issues (Marino 2019), (Oman-Reagan 2019), (Potthast 2019), (Billings 2019), (Traphagan 2019); challenges related to the social and psychological life on Mars (Tachibana 2019); a careful approach to future colonisation of space (Smith 2019), and a moral imperative and obligation to colonise space (Green 2019), (Munévar 2019).

Note 2. We use the term "ethics" to mean a system of values-based guidelines consistent with a specific society's culture. Ethics assist humans to make decisions based on a culturally consistent scale of "right" and "wrong."

Note 3. Representatives of the restrictive approach generally accept the idea of human enhancement but they identify some potentially negative consequences, like the social equality challenge or the risk of cheating, to mention but a few (Giubilini and Sanyal 2015, 236). The basic distinction in ethical debates includes permissive, restrictive and conservative standpoints, or transhumanists and bioconservatives (Bostrom and Savulescu 2008).

Note 4. Difficult conditions on Mars and the hazards associated with space flight may lead to a scenario in which the first settlements (bases) will be established by the military. Much depends on the course of settlement of prior lunar bases and the relative success of a United Nations-type of administrative structure.

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