Chapter

Astrosociology on Mars

Jim Pass

Abstract

This chapter focuses on the importance and need to focus much more strongly on the social and behavioral sciences, humanities, and arts regarding the study of space issues, and Mars issues specifically. The particular focus here deals with the vital need to balance planning for Martian settlements between the two major branches of science [i.e., (1) the physical and natural sciences plus the STEM disciplines and fields and (2) the social sciences, humanities, and arts]. The current focus on settling Mars is on transportation issues and physical infrastructure construction of habitats or cities. In contrast, the arguments made here support the idea that planning for Martian settlements must include the "other" branch of science, and this extends to the monitoring of social interactions and other forces associated with the complexities generated by a growing population existing in an isolated and dangerous ecosystem on another planet. On Earth, the social sciences are vital and they will be on Mars as well. Astrosociology is a multidisciplinary academic field that studies issues related to space exploration, settlement, and other issues from social-scientific perspective, and it is complementary to the so-called "hard" sciences. Collaboration on a much more extensive basis is already overdue.

Keywords: astrosociology, astrosocial phenomena, social sciences, humanities, arts, Mars, settlement

1. Introduction

Rockets and rocket scientists will be critical for getting humans to Mars, as will be those from the other STEM disciplines (i.e., the physical and natural sciences, technology, engineering, and mathematics). However, getting to Mars represents only part of the equation to help settlers to survive and thrive. Arriving safely is only part of the problem, and it importantly involves a great amount social-scientific input. On arrival, a safe physical habitat is essential, but a safe social environment within it is essential as well. It is important to remember that "expanding the human presence into space is about more than machines and missions. People are involved, with all their complexities and variations in beliefs, priorities, and behaviors" [1]. Social science matters on Earth and elsewhere [2]!

Thus, a major theme of this chapter is the emphasis on the two branches of science (i.e., the physical and natural sciences vs. the social and behavioral sciences, humanities, and arts). Specifically, this theme emphasizes the need for convergence between the two branches with regard to space issues [3]. For brevity from this point forward, whenever the term "social sciences" is presented alone, it also refers to all non-physical and non-natural sciences (as does the term "astrosociology"). This includes disciplines and fields such as sociology, anthropology, psychology, history, archeology, and all of the humanities and arts.

The arts are important as exemplified by the STEAM movement, which adds the arts to STEM, and the arts have always been a part of the astrosociology multidisciplinary academic structure. While the arts have received renewed attention, the social sciences and humanities are only recently beginning to receive their just due. Relatively speaking, however, they are still far behind the STEM disciplines in terms of recognized importance, as exemplified in the social media and literature. More about the arts follows in a subsequent section.

With this in mind, the purpose of this chapter is to explore the ways in which the social sciences can, and hopefully will, contribute to the human exploration, settlement, and thriving within the ecosystems on the Martian surface and the surrounding space environment. It is meant to complement the other chapters in this book. The purpose is not meant in any way to downplay the importance of the STEM disciplines and their contributions, but rather to focus on how the social sciences can supplement and enhance them. Separation has worked somewhat well in the past, but it is unlikely to continue its efficacy as humans begin migrating away from their home planet. The main theme here is that greater collaboration and cooperation is needed immediately, especially before mission planning is involved.

An important thing to remember is that this treatment of astrosociology on Mars deals with a future scenario in which a large and growing population is traveling to Mars. Smaller efforts are likely to precede this outcome. However, it is not too early to consider these issues now. In fact, many of the elements of discussion here will be relevant to the very first human mission to Mars.

2. Astrosociology defined

Before moving forward with this discussion, it is important to define the academic field of astrosociology. First, this field exists to encourage and foster greater participation of professional social scientists and humanists who may otherwise focus on other areas. Second, astrosociology exists to attract students with social-scientific orientations to study outer space issues, something that most of them would not have considered very long ago. Third, a very important aspect for gaining a greater understanding of space issues is to collaborate with space-based STEM fields; that is, the traditional space/aerospace community. These three components together make it possible for humankind to increase its scope of knowledge beyond just an overwhelming focus on one branch of science. The physical and natural sciences are enhanced by astrosociology because the human dimension complements them [4].

In 2004, there was very little progress among the social science disciplines, so it became a situation that needed resolution. Astrosociology is defined by this author, who also founded this academic field, as the study of astrosocial phenomena (i.e., the social, cultural, and behavioral patterns related to outer space) [5]. Astrosociology is not just sociology, as astrobiology is not just biology. It consists of sociology, anthropology, psychology, economics, political science, history, space law, and much more. The "sociology of outer space" or the "anthropology of outer space" can exist simultaneously with astrosociology [6], but this academic field is more inclusive and can work with the other approaches. The multidisciplinary aspect involves the social and behavioral sciences, humanities, and arts. It is important to keep in mind that astrosociology exists in order to balance the traditional approach so that the two branches (or cultures) of science can better collaborate in a more productive way. Astrosociology bridges the Great Divide between the two branches of science, as depicted in **Figure 1**. This clearly results in greater progress because the human dimension is added to the equation.

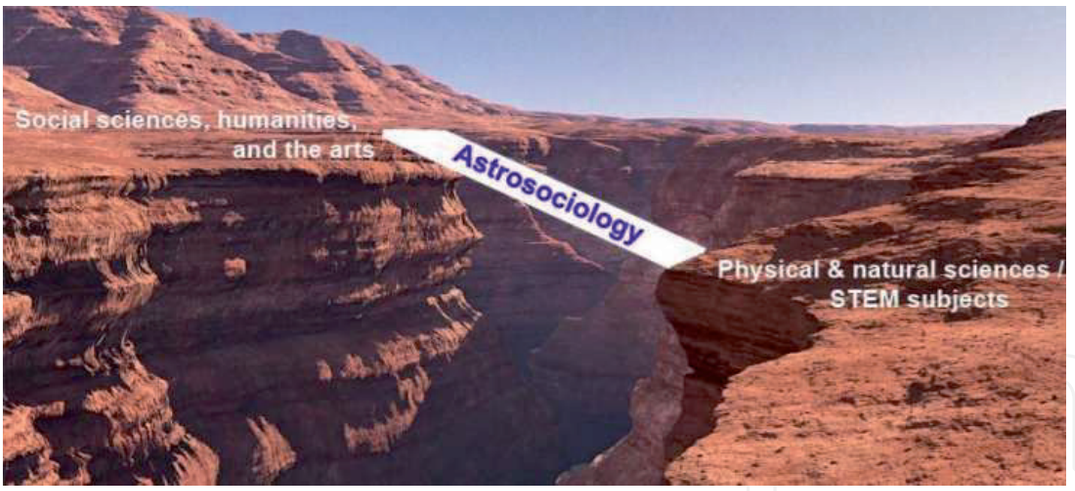

Figure 1.
The great divide bridged/photo credit: Jim Pass.

The purpose of astrosociology is to construct a cohesive literature and build a community of like-minded social and behavioral scientists, humanists, and artists who focus on astrosocial phenomena and strive to work together [7]. As mentioned earlier, there is a commitment to collaborate with those in the space-related STEM disciplines to forge a holistic understanding of space issues affecting those living and working on Earth and in space, including the interactive effects between the two. The overwhelming and detrimental fact is that astrosociologists remain far behind physical and natural scientists in terms of contributing their equal share of input to the outer space knowledge base. Relatedly, there is much historical and behavioral research from the social sciences and humanities that is applicable to helping plan for social life on Mars.

3. Physical science and social science contributions

Accordingly, this author founded astrosociology in 2004 due to the lack of social-scientific input into the study of astrosocial phenomena [8]. This was always a relative situation, however. When it is compared to the input by physical and natural scientists, the overwhelming emphasis remains on the STEM-related issues and concerns, and therefore the overwhelming funding goes to non-social-science individuals as well as private and public entities. The equal distribution and attention to social science will likely never reach that of physical science, but a substantial increase is sorely needed at a time when sending hundreds of people to Mars is seriously being considered by the Space Exploration Technologies Corporation (SpaceX).

To be fair, scientists and scholars from the physical and natural sciences such as the search for extraterrestrial intelligence (SETI), astrobiology, astronomy, planetary science, planetary defense, space architecture, and engineering have recognized the potential of the social sciences and humanities, and they have worked with social scientists in some instances. Examples include Ben R. Finney [9], Christopher McKay [10], Penny Boston [11], and Seth Shostak [12]. Too many exist to reference here so the reader is urged to do research to find them. An early place to start is this reference from 1988, which is an edited book that actually includes physical *and* social scientists [13]. This additional publication is a good example of a social scientist (an anthropologist) and a space-related physical scientist (an astronomer) working together [14].

This recognition is important because it opens the door to the realization that the social sciences are relevant. It is also problematic because physical and natural scientists are not well versed in the social sciences unless they work with social scientists. This area of knowledge, which includes sociology that is over 200 years old in terrestrial societies, is more relevant to study social science issues related to space—that is, astrosocial phenomena—because they possess the expertise. For this reason, the best overall approach is for the two branches of science to cooperate and collaborate on a formal basis.

Social scientists and humanities scholars have, in fact, contributed to the study of space issues. This trend increased somewhat during the early days of the space age when science did not know if astronauts could functional well mentally and physically in space environments [15]. Rudimentary space psychology existed to monitor National Aeronautics and Space Administration (NASA) astronauts before the United States launched its astronauts. It continued starting with the Mercury program during training, missions, and afterwards. Space psychology and psychosocial research continues today [16, 17]. Space historians also played a large part throughout the space age and they also continue to do so into the "NewSpace" age, which is characterized by commercial space activities [18–21]. Many other social scientists have also contributed in meaningful and less impactful ways. Again, there are too many examples to go into detail here, but they are listed in the reference section as a good starting point [22–37]. There are many more examples, and even this listing may seem quite overwhelming, but these social scientists represent just a trickle of contributions compared with the physical and natural sciences during the advent of the space age through today. There was a concern about the lack of social science input. For example, Rudoff voiced it succinctly in 1996 when he asked, "And where is sociology?" [25], p. 75. The other disciplines were also silent.

"The social sciences and humanities cannot afford to remain silent, and the traditional space community cannot afford to allow them to remain so" [4]. One of the most frustrating realities is that many social scientists work in isolation, which is a central reason why this author created astrosociology. It is intended to provide for a community in which social scientists can more easily collaborate and create a cohesive and easy to locate literature. This is changing, however. It is hoped that the creation of astrosociology and the work of the Astrosociology Research Institute has played a part although the increasing impact of astrosocial phenomena in larger culture have also contributed apart from it as well. It is hoped that the future will yield a much better level of collaboration between the two branches of science as time passes.

4. The Astrosociology Research Institute (ARI)

In 2008, the Astrosociology Research Institute was created by this author in order to advance the development of astrosociology beyond 2004 when this author first founded this academic field. The mission of ARI is to facilitate opportunities for others and to contribute directly to the development of astrosociology. ARI is a 501(c)(3) nonprofit educational and research organization that depends on donations to advance its mission.[1] It also depends on the participation of volun-

[1] ARI's webpage is the following: www.astrosociology.org, which includes the Virtual Library and donation page.

Figure 2.
The ARI logo and the planet Mars.

teers to contribute to its development. Regardless of its resources, ARI continues to promote and advance the need for the social sciences to become more involved in research and educational efforts related to outer space exploration and related issues.[2] Settling on Mars requires more research by professional social scientists and their students, as **Figure 2** represents. At the moment, too few opportunities exist for social science majors and graduate students to pursue astrosociology at their universities and colleges.

Therefore, another important part of ARI's mission, besides encouraging social science and humanities professionals to take part in astrosociological education and research, is to help interested students to gain access to the study of astrosociological issues. Related to this is the "Astrosociology in the Classroom" program. It encourages educators and programs to include astrosociology in their classes and to even create entire courses.[3] ARI is dedicated, among many other space-related issues, to getting many more social scientists involved with Mars education and research focusing on a number of fronts, many of which are covered in this chapter.

Students pursuing STEM-related space science degrees are encouraged to also take social science, humanities, and art classes. Professionals from the space sciences seem to be increasingly recognizing that the so-called "liberal arts" are valuable to their own research. This author is also being contacted much more frequently recently about astrosociology. A more holistic education results in a more holistic approach to understanding astrosocial phenomena.

[2] Materials from this author and others, which include issues of the *Astrosociological Insights* newsletter and *The Journal of Astrosociology* are available at no cost in the Virtual Library at www.astrosociology.org.

[3] The first ongoing course was introduced at Harvard University by Dr. Gerhard Sonnert who is now a member of ARI's Advisory Board and Editorial Board for The Journal of Astrosociology.

5. The meaning of "Astrosociology on Mars"

"Astrosociology on Mars" reflects the need to place social scientists—astrosociologists—on the Martian surface along with the expected STEM-oriented individuals. Both branches of science, the physical and the social, provide benefits to settlers, as they must cope with issues in their physical and social environments. They must interact within their physical space with one another. "Astrosociology on Mars" most importantly refers to the need to put *astrosociologists* on Mars!

More broadly, the "Astrosociology on Mars" concept refers to the vital need to include social and behavioral scientists, humanities scholars, and space architectural artists in the planning for human-based ecosystems in the Martian environment on a permanent basis. Just as importantly, it refers to the vital need to include them in these ecosystems in order to help set up social institutions and continue to study the behavioral patterns of the members of social systems as their populations increase: from bases, to communities, to space societies. Each significant population increase results in exponential rises in complexity in the population's behavioral patterns and thus an increase potential social problems.

The social sciences are vital to the functioning of terrestrial societies and there is predictably even a greater need for this type of research in Martian settlements. Unlike isolated habitats on Earth, such as underwater facilities, submarines, and Arctic and Antarctic bases, the perception of returning back to terrestrial civilization seems unlikely, or at least months away, which can result is mental and social problems for some individuals. Without the input of astrosociologists on Mars, chaos and conflict in addition to other forms of deviant behavior is much more likely to occur, as the stressors generated by confinement and isolation on another planet can cause great behavioral disruptions. Research on Earth focusing on similar settings, both related to space and unrelated directly, have provided invaluable knowledge and insights. See these publications, which provide important examples (although a large number of others exist as well) [13, 38–41].

Astrosociology on Mars is essential to humans settling there because their lives depend on social order and cooperative interactions. Thus, they are just as important as the life-giving contributions of the physical and natural sciences and engineering technologies. The physical structures must make staying alive possible, so they are necessary although they are not sufficient, and thus the social structures must also exist to make social life possible. The social sciences and physical sciences to work together, as both are necessary for life at the planet Mars. They must work in concert with one another. As such, astrosociology belongs in the Martian settlements along with the physical sciences. Generally, astrosociology exists to bridge the chasm between the two major branches of science as depicted in **Figure 1**.

6. The astrosociological imagination

The concept of the sociological imagination was introduced by sociologist C. Wright Mills in 1959. In this sociological context, he stated that it is important to recognize and understand relationship between the self and society, to possess "the vivid awareness of the relationship between personal experience and the wider society [42], p. 6." Specifically, he stated that "The sociological imagination enables us to grasp history and biography and the relations between the two within society. That is its task and its promise [42], p. 6."

Application of the sociological imagination to the field of astrosociology allows for the introduction of the *astrosociological imagination*. "The astrosociological imagination is a high-level conceptualization; it is an insightful way at looking at

the world that allows a person possessing and exercising it to make connections between his or her personal world of experiences and the macro-level (larger scale) existence of astrosocial forces [43]." It is an understanding that personal experiences alone do not reflect the totality of reality.

Thus, the specific focus on the vivid awareness of the relationship between personal experience and the impact of astrosocial phenomena is an important case because a substantial portion of any given society fail to recognize their relationships to the overwhelming and increasing influences of space activities. This includes policies and actions. It also includes the hidden forces that tend to exist out of the attention of the average citizen. Many citizens regard the money spent to explore space and humankind's place in our universe as a waste of tax dollar and private investment as a waste as long as terrestrial social problems require attention. This Earth-centric view lacks the vision necessary to understand the present impact of space activities and the foresight to imagine how much more they will impact on humans wherever they reside.

Why is the astrosociological imagination important to humans settling Mars? A key reason is that the astrosociological imagination broadly speaking is vital to recognize the relationship between individuals and the larger Martian social society. More important in many ways is the fact that living on Mars means that space has a much greater impact on everyday social life. Therefore, possessing a strong astrosociological imagination becomes vital to not only recognizing less obvious impacts on people's lives, but also vital to survival. The physical environments, and thus the ecosystem within the habitat are much more dangerous and require acute attention to the obvious social forces as well as the underlying patterns. Lacking the astrosociological imagination on Earth is disappointing, but lacking it on Mars can become injurious or even fatal.

7. Planning before launch, during transit, and once arriving on Mars

7.1 On Earth, before launch

On Earth, planning must involve the social construction of the settlement as a theoretical model that takes into account the intricacies of a social system that has never existed. Depending on those who lead the planning effort, the type of Martian society will differ so that its characteristics and functional details align with their priorities. Planning must occur on Earth before the first launch so that the earliest days of settling the Red Planet becomes as optimal as possible. Planning an ecosystem early in the process increases the odds of success [44].

Astrosociology on Mars begins as "Astrosociology on Earth" in the sense that the human sciences must be involved in providing invaluable insights as to the astrosocial phenomena that will inevitably impact on the success of any space mission, whether temporary or permanent in nature. The contributions by social scientists from the planning stage onward remains undervalued to a perplexing extent, but their importance needs to be understood in terms of their true impact. Too few contributions can result in a failed or chaotic outcome while an adequate level of contributions can assist with the physical aspects and, more directly, on the behavioral aspects while in transit and after arriving on the Martian surface. Currently, the social sciences and humanities continue as a neglected category in the planning stages and beyond.

Sending tens, hundreds, or even thousands of humans to Mars in a relatively short period of time is not recommended without input from astrosociologists. As a theoretical enterprise, consider what would occur if 100 individuals were sent to a deserted island without the knowledge regarding how to construct a functional

social system. The trial and error attempts to reach a civil community will inevitably result in harm to some individuals without social-scientific expertise being infused in the planning.

Just as the construction, planning, and testing of the hardware is an essential component, which gets people to the red planet, construction of the social system on the ground is also vital. While it may take 6 to 8 months to travel to Mars, life in the Martian settlement will last lifetimes and perhaps generations if all goes well. It is therefore imprudent to expect settlers to construct the social system of a functioning settlement only after they arrive.

7.2 Life in the spacecraft during transit

During life in the spacecraft, the theoretical construction of the settlement must become implemented as a practical, functioning version. For example, the culture must be understood by the population and rules of behavior, the social norms, must be accepted, including penalties for violations. "A central assumption made here is that the population that ultimately leaves our planet together must be socialized into a single social order that exists before boarding their spacecraft; and they must largely accept the ideas (including values) and the norms or social rules that protect these values that comprise a single culture, which is part of the social order [44], p. 3." Details about culture and social structures follow in subsequent sections.

The long journey to Mars makes it imperative to provide structure and understanding among those in the population about what types of behaviors are acceptable and which are not. This stage of settling Mars provides a shakedown of sorts that put the plans made on Earth to the test. It must be structured in order to acclimate travelers to the social system and culture, and so that they know what is expected when they arrive at Mars.

This stage of the settlement mission will be characterized by boredom, largely because a great majority of the voyage will be automated [45]. There will be extreme challenges on the long-duration trip to Mars [46]. The best way to meet the trials involved so that stressors are minimized is for the physical and social elements to work together. The astrosociological approach involves collaboration and taking advantage of social-scientific knowledge available today and that learned in the future before the mission begins. The more knowledge that can be implemented in the planning, the better the experience on the voyage to Mars.

7.3 Once arriving at Mars

Once arriving at Mars, settlers must put the predetermined plan into operation. The transit phase will allow for adjustments to the original plan to be put into practice, as problems and other unanticipated issues will have undoubtedly arisen. With a good original plan as a starting point coupled with the lessons learned during the trip to Mars, the construction of the social system and the physical components of the habitat can help ensure a better organized starting point, even with the difficulties that will exist. This eventually would not be nearly as practical without the original plan that was formulated on Earth, and of course, the great bulk of this chapter focuses on this arrival stage.

8. Physical and social environments

Physical environments include the spacecraft and habitat structures while the social environments include the interiors of these physical environments where

humans live and interact. It is important to distinguish between the two. Planning regarding the physical and social aspects must receive equal attention because the construction of the social ecosystems is just as important for the survival of the inhabitants as the construction of the physical components [47]. "Although engineering solutions can construct a physical environment that can sustain the population on a biological basis, this capability cannot ensure the success of the settlement due to its inattention to the critical issues related to the social environment" [48], p. 554. They must be also integrated as one whole entity. If one of them goes "out of whack," it places strains on the other. There is a balancing act in which living in a Martian habitat constantly requires monitoring.

Determining where to place a settlement, such as choosing between the surface or lava tubes, for example, can have implications down the line for the social environment. "Lava tubes on the Moon and Mars are of interest for space settlement because caves have been proposed as natural shelters that future human explorers could occupy. Caves would in principle protect dwellers from surface radiation, wide temperature swings, micrometeorite impacts, and rocket exhaust blast" among other benefits [49]. Another potential benefit is that life support requirements could be simplified. This could thereby reduce the rate of resource use due to fewer precautions that would be needed to protect settlers and their equipment.

Alternatively, a surface settlement would need to implement greater resources and strategies to protect the settlement and its occupants. Existing on the surface could provide easier access to the objectives of settlers such as accessing water, greater mobility to different areas including the use of rovers, and better access to searching for Martian life. The decision regarding which type of environment is chosen will be based on a cost-benefit analysis based on the objectives of the leadership. Another alternative, if practical, is taking advantage of both options in a fairly small area. Again, physical and social criteria must both be part of these calculations.

As this chapter emphasizes, the social environment cannot receive too little attention by planners during the first two stages and astrosociologists must be ready to conduct their research once construction of the Martian settlement begins. Future Martians will need to cope with the same interpersonal issues that populations on Earth do, but in far smaller and more confined social settings. And, in fact, more challenging living conditions can easily aggravate social interactions due to the harsh Martian conditions outside of the habitat components including the mainly carbon dioxide nonbreathable and thin atmosphere (see **Figure 3**), cold outside temperatures, solar radiation, seasonal dust storms, and the lack of even the simplest conveniences.

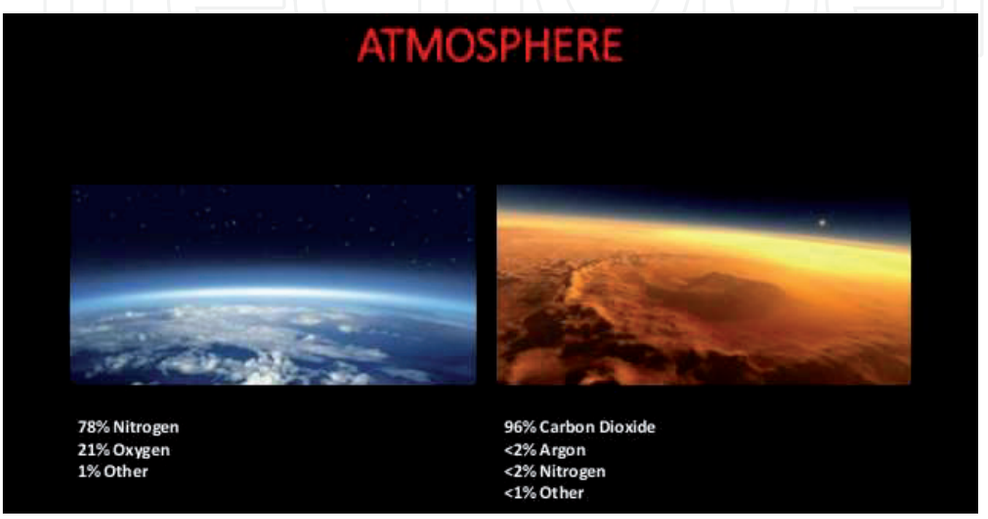

Figure 3.
The comparative atmospheres of Earth and Mars/photo credit: NASA.

Habitat structures must provide adequate opportunities for Mars settlement citizens to be able to socialize, to interact when they need to be around other people. Compartmentalization, which is often depicted in artistic renderings, is not a prudent design when carried too far. Privacy is important although isolation is not healthy when socializing becomes difficult under these types of isolated and enclosed conditions. The social environment, the ecosystem inside the habitat, must become increasingly designed as it grows in size to limit isolation among those in the growing population. This should be integrated into the original plan. Space architecture should also make the design within the physical structures more like a community and less like a spacecraft or base.

9. Space architecture and art

There has been an increasing need to develop the field of space architecture for designing and building progressively complex spacecraft, especially those carrying humans, and for getting a jump on the habitats slated for the Moon and Mars in the probable near future [50]. "Space architecture is the theory and practice of designing and building environments for humans in outer space [51], p. 890." Mars habitat simulations conducted by the Mars Society [52], NASA, ESA, and others have tested hardware and have increasingly focused on social-scientific areas of research as well. **Figure 4** shows the Mars Society's Flashline Mars Arctic Research Station located on Devon Island, Canada. Work in these types of analogs produce valuable science that amend submarine, aircraft carrier, and terrestrial Arctic station research efforts among others.

Living in a space habitat for the rest of one's life presents adjustments, which impact different individuals in various ways. The transition from the long trip to Mars aboard a spacecraft characterized by weightlessness to one that characterized by a gravity field that is one-third of Earth's will present settlers with physical and psychological adjustments that must be made. "Through the body, sensorial data and emotional response interact to create symbolic meaning that ultimately impacts the development of new spatial habitats. The creation of such 'places' requires the understanding of the human environment interface and integration of territories

Figure 4.
Flashline Mars Arctic Research Station/photo credit: Mars Society.

that range the psychological, social, ergonomic, anthropologic, perceptual, and anthropomorphic that radiate into interconnected and intra-disciplinary fields [53]." Astrosociologists on Mars also entails conducting research while on the voyage to Mars. Understanding how well or how poorly various passengers faired in weightlessness presents the researcher with challenges that entail helping each individual adjust to his or her new life on Mars.

Functional hardware alone does not result in a functional society. The human dimension, which involves social interactions and reactions to living conditions, is just as important on a medium and long-term basis. At its most basic level, the construction of the physical habitats and other structures will be built with operational functionality in mind for various purposes without regard to the humans that inhabit and work within them. Moving beyond that standard takes into account the human beings and the ecosystem in which they live. The physical structures have direct and indirect impacts on the social structures in the various habitat components.

Space architecture, when implemented to benefit the people, moves beyond the minimum standards of function. It adds layers onto the basic survival standard. Space architecture can make living in a Martian settlement survivable, which is, of course, vital for any life, but it can also make the existence there livable and even enjoyable. The adventurous attitudes present in the initial planning and training on Earth will likely give rise to practical thoughts about the hardships that lay ahead during the voyage to Mars. Therefore, the architecture of the spacecraft is important, but the construction and details paid to the social environment of the habitat components is even more critical because that is where they will spend most of their time, even their entire lifetimes.

Art, as part of the construction process, can also provide an esthetic that reminds inhabitants of Earth. While "space art" generally depicts the wonders of universe, Earth-based art can go a long way to improve living conditions on a psychological level. It can also provide a sense of homeness as opposed to a stark minimalist enclosure. A military style is probably acceptable for small and temporary quarters such as the International Space Station. A military or quasi-military purpose is the legacy of the space age thus far, but individuals with nonmilitary statuses and roles will not adjust well in that type of political system.

A large and growing population will need to establish an organic form of solidarity, which is social cohesion that is based on members of the population forming a dependence on one another, which includes diverse statuses or social positions [54]. Contrastingly, the mechanical form of solidarity is characterized by most of the people sharing common values and beliefs, which is workable for a small crew but not feasible for a growing settlement [54]. Astronauts at NASA are trained very intensively and similarly in order to perform extremely well-choreographed scheduled tasks. They are taught to improvise during emergencies though these are rare occurrences. In contrast, settlers on Mars will be much more diverse with educational backgrounds and experiences that may have little or nothing to do with running the settlement politically, engineering-wise, or performing various forms of maintenance.

Architecturally, the best approach is to make social settings within the habitat components as reminiscent of Earth as possible rather than simply following a functional scheme that fails to take advantage of the psychological, social, and cultural requirements of settlers that transcend meeting engineering standards. This will be most important for early habitats. As habitat structures increase in size and sophistication, the needs of the humans on Mars should become higher priorities. At first, in contrast, the engineering issues will prevail in order to allow for settlers to survive on the Red Planet.

10. Martian settlement cultures

Every base, community, city, or society on Mars—or anywhere else—will include a culture that shapes behavior. It defines how we live in a particular society and includes the characteristics of the people who live in that society. The popular meaning of culture that includes popular movies and music, as two examples, does not apply to this discussion. The social-scientific definition, which is discussed in this section, is quite different.

Settling Mars is a cultural invention. "Of course, all rationales for space activities are cultural [36], p. 31," which means that how settlers organize their physical and social constructions will be based on ideas carried with them from Earth. "Culture is inescapable. [36], p 31" In the case of settling on Mars, rationales include exploration in order to gain scientific knowledge, the adventure related to living on another planet, and ensuring that the human race survive in case of a global catastrophe on Earth. Mars has long fascinated humans and has gone through a number of different phases, the last of which is viewing Mars as the new frontier, but this cultural idea could well result in transposing past terrestrial problems onto the Martian surface so that not enough would be learned from history [55]. Bringing imperialism and various social problems to Mars is something that needs avoiding whenever possible. Harmful cultural ideas represent unneeded baggage better left behind.

Here, the definition of culture encroaches on social life much more than the popular meaning even though popular notions can represent reflections of the social-scientific definition. Interestingly, however, many of the impacts of culture are not always recognized and understood by the general public as forces that affect them. The analogy has been made by many that "culture is to humans as water is to fish." This analogy points out that fish depend on water to survive just as humans depend on culture to survive in their society, but neither recognizes it. At Mars, the evolving culture will have the same impact on settlements and settlers. And, as discussed earlier, a well-articulated culture should be part of the planning process before lifting off for Mars.

In 1970, sociologist Robert Bierstedt identified three dimensions of culture as consisting of ideas (including values), norms (i.e., social rules), and material culture [56]. The ideas in culture provide citizens with the important priorities and acceptable standards of conduct. Norms exist to protect values. Material culture consists of the physical creations of humans in society (i.e., the physical habitat components, rovers, and spacesuits), which will become increasingly important as they are constructed and their meanings become integrated into the larger culture. These meaning can evolve into changed ideas over time.

While important, the larger culture does not totally affect all individuals and social groups in the same way. There are contrary forces in any society. Settlers from different terrestrial cultures can interact in ways that result in conflict within the same settlement or between different settlements, as can religion-based differences, for example. Subcultures exist that may oppose some aspects of the larger culture while countercultures oppose the dominant culture itself. Thus, while subcultures may produce social movements, countercultures can produce revolutions, even in a Martian settlement. Astrosociologists on Mars will need to monitor contrary patterns of behavior that will inevitably arise.

11. Social institutions on Mars

Social institutions regulate behavior, as they are part of the social order of a society. They consist of people who share a common purpose. This definition is at

odds with the common public view that may view the courts or schools as institutions because they are components rather than the entire institution. An important consideration is the fact that social relationships become progressively complex as the population increases in size. As such, social institutions become increasingly more important and their missions become increasingly complex and thus more difficult.

Any settlement on Mars must involve well-defined social institutions in order to control behavior. Haphazard plans of constructing the settlement both physically and socially will result in a level of chaos that can easily lead to the failure of the settlement to sustain itself even with adequate supplies from Earth. Moreover, the physical and social constructions are intimately interconnected, which means that addressing both types as a single system is vital. As such, planning before the mission begins, including devising a culture and a set of norms, cannot be overestimated even while most existing plans seem to downplay or even ignore this requirement [44].

Below are brief issues related to some of the most important institutions of any human social system. Each requires substantially more attention in the future. Nevertheless, pointing them out here is a good start, as they are brought to the forefront of a Mars-based discussion, which does not occur nearly enough.

11.1 The economy

The economy is an important institution to consider because, among other things, it determines how resources are distributed to other institutions, groups and other entities, and individuals. At Mars, the economy initially will be rather straightforward and dependent on supplies from Earth. As time goes on, however, Martian resources may well build production in several areas that can lead to exchange functions with entities on Earth. In general, how fair the resources are distributed is an important issue for astrosociologists.

Settlers must feed themselves, which means that they will rely on sources of nourishment. This will become increasingly more difficult as the population increases. While growing food in greenhouses will be necessary, most resources will come from Earth. The early Martian economy will be difficult to sustain requiring much hardship at first. Over time, the economy can begin to flourish as settlers take advantage of in situ resources and develop unique services such as tourist destinations such as rover and lander monuments, or hotel lodgings.

11.2 The political system

The political system is a vital component that determines how the settlement functions. Who governs? Will the leadership be characterized as a military, quasi-military, democratic, authoritarian, totalitarian, or charismatic political system? The structure and actions of politics can shape the structure of the social system and quality of life of citizens. Therefore, the comparison between two settlements could very well reveal significant differences between the two on a number of social and cultural dimensions. The experiences of each of the populations could be quite different. What type of class system will exist upon landing, or even en route, and how will it evolve in the future? How will different categories of people be treated? Will discrimination be an overwhelmingly harmful characteristic?

As we have witnessed on Earth, the leaders change over time and they can move in extremes such as from a democracy to a charismatic or even totalitarian orientation. Astrosociologists will need to conduct research to determine how the political system functions and what changes occur. This is another example of the importance of social scientists on Mars.

11.3 Criminal/juvenile justice system

Criminal/juvenile justice system operations exist to ensure social order by acting proactively and reacting to unlawful behavior. One thing that is certain in all human societies is the fact that deviance is a cultural universal and will exist in any social system, including on Mars. Therefore, it is important to devise a preconception of a justice system that can handle violations of the law and conflict that may arise even during travel phase before reaching Mars. Relatedly, laws must be understood by the population and protected by law enforcement. Equality in policing and court decision making must be seen as fair. Otherwise, protests can arise as is evident in terrestrial societies.

Enforcement of other types of norm violations such as those involving the health and safety of settlers is also an important consideration, especially in an enclosed and confined living situation in which a single mistake or act of sabotage could have deadly consequences [57]. Overwork could lead a person to cut corners during maintenance activities or inspections. Unsafe conditions may also result in protests and more serious reactions. This is an important aspect of life in a Martian settlement that requires constant maintenance and inspections in order to ensure health and safety standards for the protection of the population.

11.4 The family

The family is an institution that receives little attention in the midst of attention to other issues related to settling on Mars. While children would be highly unlikely to go to Mars initially, couples will very likely be in the population. Additionally, romantic relationships will undoubtedly develop and that could result in children down the line. Support for families would be required including their rights and supportive policies.

Family structures will differ, as they do here on Earth, which is something that is important to monitor. Some structures may receive condemnation by official sources including other institutions that may result in inequality suffered by family members. Hardships caused by the harsh conditions on Mars from the environment outside and the ecosystem inside (including isolation) can produce stressors and strains between family members and couples that endanger their relationships even when inequality is not the root problem.

11.5 Religion

Religion can foster fellowship and community within the population, but it can also cause conflict between religious groups and individuals with different religious backgrounds. Atheists will also impact on this social dimension. Some forms of tolerance policies should exist so that harmony rather than conflict exemplifies the religious dimension. In any case, "living in close quarters in hazardous environments will make interreligious dialogue all the more important..." [58]. Settlers will need to find a way to get along if the settlement will be characterized by a minimum of religious-based deviance.

Politics can influence how the institution of religion interacts with non-religious institutions. Will there be a sort of separation between religion and state? Conversely, will the settlement's government promote secular society or be based on a religious dogma such as Christianity or a sect of the Muslim faith? This example demonstrates how social institutions interact and complicate social life in any society.

There is another interesting possibility. Living on Mars could well involve social forces that produce one or more new religious groups in the form of cults (new religions), sects (fully branched off religious groups), and new denominations (slightly offended branches off religious groups from their established

churches). These types of evolutionary occurrences could add new complexities to the social system. Cults and sects may challenge other religious groups or the Martian government itself. Religion is an inevitable dimension of social life that requires social-scientific scrutiny, just as all others.

11.6 Education

Education is important, not only for children and young adults who would arrive later in the migratory process, but also for older adults who must learn how to live in the new settlement. New members need to learn the differences from Earth that they first encounter in a substantially new and different ecosystem. For example, they cannot easily go outside of the habitat components and must learn to live in a confined and enclosed ecosystem.

Additionally, settlers, especially early in the construction of the settlement, will need to learn new skills and concepts. They will need to conduct multiple tasks and teachers will need to pass them on to new settlers as they arrive. The needs of the settlement will change over time so that arrivals will not always possess the most desirable attributes.

11.7 Health care

Health care is an extremely important issue in harsh environments such as that of Mars. The potential for illness absolutely increases due to the harsh Martian conditions that include solar radiation and the one-third gravity field. Ethical issues include right-to-die disagreements and the potential inequitable distribution of medical resources, which will be limited [59]. Conflicts or disagreements between patients and/or their family members and medical practitioners can result in conflict. Social problems such as racism, sexism, and classism can affect the quality and very implementation of life saving interventions as witnessed on Earth. (See the medical astrosociology section below for additional details).

11.8 The military

The military on Mars may exist in order to protect one settlement from another's transgressions once they begin to appear. Another possibility is providing defense against entities on Earth that they fear may interfere with their operations and priorities. This latter situation could be complicated if they a Martian settlement possesses valuable Martian in situ resources that an Earth-based entity covets. A military presence may exist just because it is how things work on Earth. The possibility of a military existence is something for astrosociologists to monitor because its members may interfere with civilian authority in inappropriate ways.

11.9 Sports and the media

Sports and the media must not be viewed as extraneous to a well-functioning Martian settlement. As witnessed in terrestrial societies, the absence of sports and simultaneously the importance of entertainment and news in their various formats demonstrate that these two social institutions provide important lessons for settling beyond Earth. It is important for the citizens of a Martian settlement to distract their attentions away somewhat from their hardships associated with living on an isolated and potentially deadly planet. Two forms of sports and media consumption exist.

First, on Mars, planners of the habitat modules—and to the extent possible aboard the spacecraft—should focus on establishing community areas because

sports and media outlets together represent extremely relevant outlets for the well-being of individuals. Live sports and entertainment events such as concerts and plays in the settlement can contribute to a rise in psychological well-being and group cohesion. Recreational activities are also important. This is different from interacting with coworkers, and thus, off-work activities must supplement it. A Martian Internet should be part of the planning process before launch. Encouraging a focus on the benefits of living on Mars, including the social interactions with others living there, is important to mitigate feelings of isolation and homesickness.

Second, the consumption of sports and media content from Earth can help negate any psychological hardships that are exacerbated by communication delays with those on Earth, as they will provide various levels of frustration among settlers. Connecting to Earth-based cultural trends, events, and people is vital, especially for new arrivals. Therefore, recorded sports events, entertainment programming such as television shows and movies, and news recordings will mitigate some of that despondence. Recorded messages that can be played without the prospect of interaction can help although it also emphasizes the disconnection among individuals on each planet. Recorded content cannot replace communicating interactively with loved ones, friends, colleagues, and others; however, a combination of communication formats will be required. Finally, a warning of sorts is important. Sports and the media must not receive undue attention because, together, they can act as a pacifier that glosses over negative sociocultural realities such as social problems that could exist including discrimination or the support of other harmful social conditions. The prospect of placation of the citizenry will depend also on the agendas of the other social institutions including the political influences. Precautions to avoid instances of community harm will require ongoing oversight by social scientists in settlements away from Earth.

12. Social problems in Mars settlements

Social problems can harm most people or specific categories of people, and they will exist in any Martian settlement. Many of the problems faced within, and between, terrestrial nations are difficult to address and mitigation is often not a priority among political leaders. Given the seriousness and ingrained nature of social problems, is it a good idea to spread these harmful behavioral patterns into our solar system and beyond?

On the one hand, an argument exists against migrating beyond Earth's atmosphere and staying put on humankind's home planet [60–62]. This position disfavors settling Mars based on a crisis of faith in which people cannot be trusted to set their differences aside and create a society that lacks social problems. Thus, space exploration, including the settlement of Mars, is not a guaranteed outcome, or at least it is not necessarily easy to put into motion and sustain. There are forces that prefer to slow down sending humans to Mars. There are other forces that want to limit the number of humans who go there in order to reduce contamination levels and the number of contaminated sites.

The contrary argument is that we *must* settle Mars despite humankind's history of conflict, inequality, and production of social problems. Advocates favoring settling other planets and space environments argue that social problems can be minimized in terms of their negative impacts based on the perceived ability to learn from history so as not to repeat humankind's worst errors. The movement to going to Mars seems inevitable with SpaceX and other private companies gearing up to send people beyond the cislunar space environment. This author foresees the inevitability of settling elsewhere

in our solar system *and* the manifestation of serious social problems occurring together just as the existence of social problems did not stop exploration on Earth.

With this in mind, it seems prudent to keep the argument against migrating into our solar system in mind while focusing on how best to make a settlement function as fairly and equitably as possible. It is best to include both types of advocates in the planning process in order to be exposed to voices that point out discriminating strategies and other forms of harm to potential settlers. An overwhelming focus on the hardware that takes attention away from the human dimension, which astrosociologists focus upon, will result in skimping on things that may bring discomfort or even danger to human beings. "Astrosociology on Mars" refers to the beginnings of the mission on Earth through establishing the settlement, and beyond, as human interaction and the functioning of the physical aspects of the settlement continue.

Social problems will continue in various forms in Martian settlements [63]. They will differ from one settlement to another just as social problems differ among various nations on Earth. Part of the determination, at least for the start of a settlement's beginning stages, will be determined by who funds the mission and the composition of the leadership. The nature of the settlement will also bear on how it functions and the priorities. A scientific mission will differ from a communal type of orientation, for example. Another settlement may be characterized by a mixture of priorities as well.

Settlers will need to deal with the various types of social problems, which include injustices. This is because they will bring them along due to being socialized in terrestrial societies. They may well possess attitudes that lead to unwanted behaviors. Inequality will undoubtedly exist that includes sexism, racism, poverty/social classes, religious conflict, and political dissent. How well the socialization during the planning and traveling stages could serve to curtail the impact of these problems is important although they will exist to some degree and must therefore receive serious attention. Astrosociologists on Mars can help with this by identifying problems and proposing mitigation strategies.

13. Space medicine and medical astrosociology

13.1 The healthcare system

The healthcare system is an extremely important social institution briefly described in an earlier subsection. Relatedly, space medicine is vital for the health and safety of settlers on Mars. Traditionally, space medicine has focused on the effects of spaceflight on the human body, which strongly involves the biological and life support issues. It is defined more broadly as the "practice of all aspects of preventive medicine including screening, health care delivery, and maintaining human performance in the extreme environment of space preserving the long-term health of space travelers [64]." Thus, preventive and reactionary efforts are involved, as countermeasures are not always effective.

These types of definitions apply mainly to living in a spacecraft and they focus on human factors rather than social-scientific principles. Human factors and ergonomics are important although not all practitioners are also social scientists. The two are complementary, however. This is important during the voyage to Mars though social science should apply more strongly even in weightlessness. However, when the focus extends to the settlement where the gravity field changes from zero gravity to one-third of Earth's, Martian medical practice will change in order to adapt to yet unknown biological effects. It will depend on the specific conditions of the planetary environment that will differ from weightlessness in outer space. Intensive research will be necessary at that point.

Before that point, the trip to Mars will likely involve a considerable time spent in near zero gravity (although artificial gravity is only a slight possibility because this option adds additional cost and difficulties in the solving engineering issues for the spacecraft). This means that the same problems faced by astronauts within the cislunar environment will be experienced by the settlers during the voyage although it may well be worse due to going from microgravity to zero gravity unless preventive actions are taken. It will be vital to keep each individual as physically fit and healthy as possible in order to reduce the physiological problems that could exist upon landing.

Some of the well-documented health issues that affect humans during space travel include radiation poisoning, DNA damage, cardiovascular stress, bone density loss, swelling of the optic nerve head, dehydration, cognitive decline, increased risk of mutations and cancer, and various molecular, behavioral, and physiological changes compared to those who continue to live on Earth. These types of detrimental effects were confirmed as a result of the NASA twin study involving Scott Kelly who stayed aboard the International Space Station (ISS) and Mark Kelly, also an astronaut, who remained on Earth [65] (see **Figure 5**). Living and working on the ISS for up to 6 months presents measurable health risks and problems, but this is mild compared to what can happen during a voyage to the fourth planet.

13.2 Medical astrosociology

By contrast, though also complementary, to space medicine, **medical astrosociology** is the study of the social, cultural, and behavioral patterns (i.e., astrosocial phenomena) that affect medical issues in space ecosystems such as settlements on Mars [66]. The reason this author created this subfield of astrosociology is an attempt to attract social scientists, especially those who have studied Earth-based medical sociology and medical anthropology in addition to students who may be interested in studying medical astrosociology. The major focus is on the sociocultural and psychological forces that affect space travelers and settlers. The effort is to bring in more social science professionals and students to work with those in space medicine.

Medical astrosociology has become part of the trend that has been moving beyond a concentration on only biomedical concerns so as to include social-scientific dimensions of health. NASA's human research program, for example, "includes many facets

Figure 5.
Astronauts Scott and Mark Kelly/photo credit: NASA.

of human space travel such as environmental factors, exercise physiology, habitability, human factors, medical capabilities, physiology, psychosocial and behavioral health, and space radiation [67]." An important aspect is determining how traveling in outer space and living in various space environments affect human biology. Producing countermeasures to harmful effects will represent an ongoing set of challenges.

13.3 Behavioral health

Behavioral health is an important aspect of assessing the well-being of a person in an isolated and confined physical environment, which involves both space medicine and medical astrosociology. It can be defined as "a lack of neuropsychic dysfunction, and the presence of high levels of personal adjustment, cordial interpersonal relations, and positive interactions with the physical and social environments [51], p. 890." When considering behavioral health, countermeasures need to be identified arising from human, environmental, and external factors [68]. The overall wellbeing of individuals must be evaluated as a combination of several medical and psychological problems along with social and cultural forces that impinge on the individual and the ability to interact productively with others. For Mars, these types of forces remain unknown until humans actually set foot on Mars. It is a holistic approach.

13.4 Space medicine and medical astrosociology

Space medicine and medical astrosociology are, in fact, complementary approaches, then, that focus on the health and safety of spacefarers and space settlers, and thus even greater convergence is needed. Together, they provide a comprehensive assessment of the condition of the patient in terms of biomedical impairment on the one hand and sociocultural, ethical, and psychological condition on the other hand. Both approaches focus on the individual and the population. Spread of disease is of importance for both, as medical epidemiology and social epidemiology possess medical and behavioral elements that provide a balance and can result in greater insights when combined together.

Living on Mars will present unique challenges, as the physical environment is inhospitable to human biology and that makes the social environment, the ecosystem inside, challenging as well. The unique Martian living conditions will present physicians and medical astrosociologists with unique issues with which they must seek to understand and then produce life-saving and/or sociocultural and psychological responses. The concept of behavioral health provides a useful approach that involves both branches of science.

13.5 Mitigating deleterious effects on Mars

Several proposals have arisen as possible solutions to mitigate the deleterious effects produced by living on Mars. For example, terraforming the Martian environment is one option to reduce health risks. However, it is tremendously difficult, time consuming, requires tremendous resources, and thus not everyone agrees that it is the best strategy to follow. **Figure 6** depicts what three stages of a terraformed Mars may look like. This is not necessarily a likely solution to living on Mars for the foreseeable future and must overcome ethical objections to even starting such a planetwide procedure. The process would wipe out any existing Martian life, even fossils that may exist, and it could add new detrimental health problems for humans. There are arguments on both sides of this issue.

Terraforming Mars would involve releasing greenhouse gases, what on Earth are regarded as pollutants, into the Martian atmosphere from a number of different

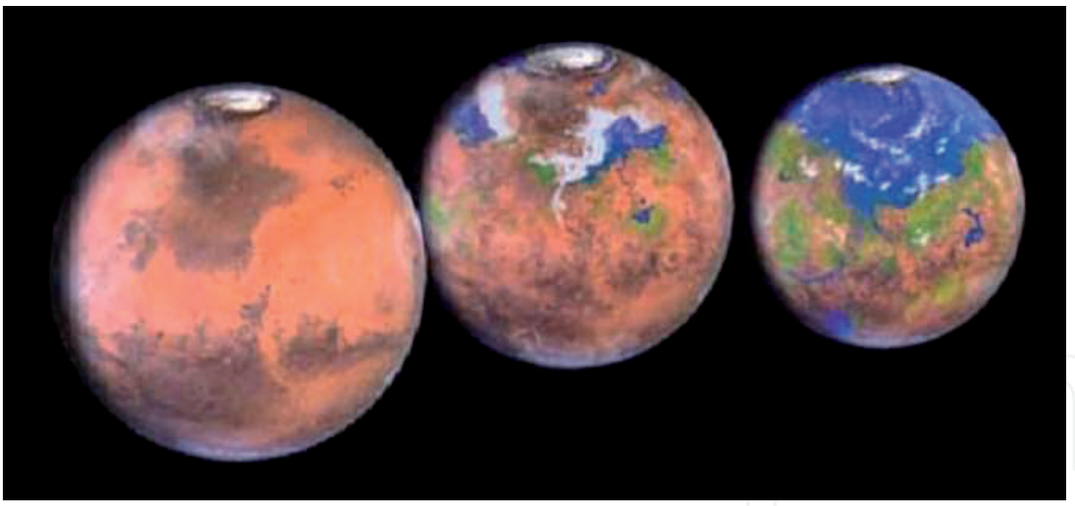

Figure 6.
Terraforming Mars/image credit: NASA.

locations on the planet in order to thicken the atmosphere and make it breathable. Such a herculean effort would take hundreds if not thousands of years. The resource expenditures and length of the process have led proponents of Martian settlement to seek other options.

13.6 Genetics and lava tubes

Genetic enhancements may better adapt humans to living on Mars physically speaking, but what will it do to the human psyche? How will it affect behavior? Is it even ethical? What about the history of eugenics? The Nazi regime in Germany instituted various forms of eugenics, which led to unethical experiments and genocide against Jews and other perceived unworthy categories of people. While altering the human body to better tolerate solar radiation, for example, may seem like a logical idea, the human experience in this area is highly problematic. Ethical questions abound such as to whether or not those who receive enhancements have clearly provided authorization.

Other proposals include living inside lava tubes, as mentioned, utilizing 3D printing to construct habitat components, and creating human made subterranean habitats. While the external environment that impacts the surface is harmful to human life that currently exist, the places where humans actually live—that is, the ecosystems in the habitat structures—present potentially equally dangerous conditions as well.

13.7 Dangers in the habitat

Life within the habitat structures is also full of health and safety threats. Simple survival requirements also present significant challenges that include providing water for humans and crops, creating an ongoing supply of oxygen, growing food in Martian soil and/or hydroponically, interacting with others on a prolonged basis within an confined and enclosed space, keeping Martian dust out of the habitat, dealing with circadian rhythm issues, adjusting to time differences (the Martian day is 40 minutes longer than Earth's), and dealing with delayed communications with Earth. Accumulating challenges could produce problematic behavioral and abnormal psychological patterns for some individuals.

Bringing Martian microbes into the laboratories within the habitat can present contamination worries. It can result in microbes escaping quarantines or otherwise infecting astrobiologists. An epidemic could arise if the microbes are harmful to humans.

Physical epidemiologists and social epidemiologists would have to work together to track the spread of disease and the structure and procedures employed to combat its spread. There are other issues that can result in health-related problems generated in the outside environment that have both medical and sociocultural implications.

13.8 Aging and space gerontology

Another issue is less theoretical and actually inevitable. Space medicine will be difficult enough without the added complications of advanced aging. Many settlers will necessarily be older based on the need for them to put their expertise and training into effect. In any case, they will age. Therefore, gerontology, defined as the scientific study of old age, the process of aging, and the particular problems of old people, will become important as everyone ages under a never-before set of medical conditions exacerbated by the Martian environment. It will involve medical astrosociology in terms of how individuals handle growing old on Mars in addition to the biomedical changes that will challenge them.

Space gerontology has been recognized by NASA and others for quite some time, in fact since 1978 or earlier. The advent of the Space Shuttle program with its first flight of Columbia in 1981 and the recognition that older astronauts would be traveling into near Earth orbit in microgravity, it became worrisome that little was known about the long-term effects of space travel as people age [69]. Nearing the end of the human life cycle in space ecosystems will produce changes, many of which will have never been experienced on Earth. Will ageism be a problem if, for example, not enough medical supplies exist for the younger members of society.

How will settlers handle death? What will cemeteries on Mars look like and what types of religious ceremonies will be held? What meanings will be attached to the deaths of the new Martians? It is quite possible that the ways that deaths are treated will evolve into one or more uniquely Martian versions of Earth observances. This type of sociocultural change is important for astrosociologists to study and understand.

Very importantly, the added complications affecting human beings in a harsh Martian environment that will inevitably impact significantly on the internal ecosystem will make implementing healthcare extraordinarily unique and difficult. What was learned regarding living in microgravity will not apply exactly the same way in a one-third gravity field. Gerontologists who also possess social science training will prove to be invaluable members of the Martian society, just as will geriatric physicians.

13.9 A few final questions and thoughts

What new syndromes or health complications will arise on Mars? How will living on Mars affect men compared to women? Will health issues affect ethnic groups differently? Will life expectancy change? These types of questions must be anticipated by both physicians and medical astrosociologists before arriving at Mars; and more importantly, monitored once the settlement is active.

While space medicine physicians focus mostly on the biomedical issues, medical astrosociologists concentrate on the social and cultural elements that interact with the biomedical aspects that can easily add further complications beyond the strictly medical concerns. This complicates how those reacting to the patient should handle any particular case. For example, are there religious factors that do not allow certain medical procedures or drugs? How do physicians and social scientists work together to treat patients, avoid discriminatory practices, and monitor the population to minimize epidemic potentials in such enclosed ecosystems? Medical astrosociology

on Mars is required in concert with space medicine and behavioral health in order to provide successful Martian healthcare. Medical and social-scientific complications will abound in such scenarios. The relationships among those practicing space medicine and medical astrosociologists will also prove to be challenging.

14. From space law to Martian law

Laws are legal norms or officially specified rules of behavior. "Outer space law encompasses both international and national law related to all aspects of space technologies, human and robotic activities and conduct, and the applicability of such laws to outer space environments and ecologies as specified in treaty, statute, or code [70], p. 3." The Outer Space Treaty (OST) and Moon Treaty were drafted to set the rules of behavior for activities beyond the Earth. They have substantial problems that seem to increase in seriousness and scope as space activities continue to increase. Relatedly, some nations such as the United States have drafted legislation that counters the intent of the treaties. If treaty provisions are not honored among terrestrial nations, what hope is there for Martian settlements to honor them?

Just as on Earth, law enforcement and social program efforts will need to react—or more importantly, if possible, prevent—violations of norms, both legal and administrative, that include being drunk in public, burglary, health and safety offenses, homicides, and a host of other behaviors that commonly occur on Earth. Humans will not act altogether differently just because they transfer to a Martian settlement. In fact, the isolation and confinement during the voyage may result in an increase in deviant behavior. Planners must therefore prepare for well-known outcomes that human societies have experienced throughout history. This is a starting point.

Moreover, what happens when settlers begin to modify or even reject treaties and laws drafted on Earth that they deem impinge on the evolving values and norms in Martian settlements? Earth-based space law exists for the benefit of Earthlings, but not all of them will apply for Martian settlers who will find themselves facing very different social forces and realities. Once humans begin to construct the physical habitat components for a particular settlement and individuals start to inhabit them, the laws established before the trip to Mars begin to evolve. (This will likely occur during the voyage to Mars).

Because laws are tied to the societies in which people actually live, they are drafted and enforced according to societal realities unique to them. On Earth, various nations enact laws that differ in many ways from those of others based on cultural identity and political priorities. Martian settlements will face uniquely challenging social forces and conditions. Thus, sociocultural change and potential social movements will produce modifications in the law. For example, will the property rights prohibition in the Outer Space Treaty be ignored or legislated as nonapplicable by settlement governments? Predictably, settlement laws will quickly start to diverge from the Earth-based case law, treaty provisions, and the traditions of terrestrial societies.

15. Planetary protection

"Astrosociology deals with the broad, societal contexts of activity pertaining to space, as well as actual space exploration including human space exploration and the search for extraterrestrial life [71]." The reference to extraterrestrial life is important because the search for life beyond Earth—especially on planets such as

Mars and Venus, and moons such as Europa, Ganymede, Enceladus, and Titan—largely depends on taking measures to avoid contaminating potential extraterrestrial ecosystems, extant life, as well as fossils. In fact, the Outer Space Treaty has a provision that emphases protection of outer space bodies [72].

"Planetary Protection is the practice of protecting solar system bodies from contamination by Earth life and protecting Earth from possible life forms that may be returned from other solar system bodies," according to the NASA Office of Safety and Mission Assurance [73]. Sterilization of spacecraft and habitat components is vital for Martian settlers with astrobiological backgrounds to make sure that they do not introduce Earth organics that may contaminate potential Martian organisms. Mistaking Earth microorganisms for Martian ones is something that they want to avoid. Others may not worry nearly as much about this issue, so astrobiologists would favor legal prohibitions that protect the potential Martian life so that proper precautions are taken by everyone. It must be taken seriously if astrobiological science is to be protected from harmful events and needless mistakes by technicians.

Placing a settlement on Mars also involves potential limitations regarding where to locate. For example, a water source would be ideal for obtaining water, but this is also where microorganisms are likely to exist. Conflicting priorities may well exist between astrobiologists and government officials. In a best-case scenario, water drilling operations that provide water for the settlement would occur in concert with attempting to limit the amount of environmental damage so that the scientific objectives of astrobiologists and others who want to protect potential Martian life can occur. Landing or placing buildings in areas thought to be good candidates for life would violate the concept of planetary protection. It will not be possible to protect every part of Mars thought to be a candidate for life. Moreover, economic commerce between Earth and Mars will place added pressures to protect the ecosystems of both worlds.

16. Exo-astrosociology on Mars

Astrobiology and exobiology represent the physical and natural science approaches to the study and search for extraterrestrial life. While the distinctions and practices that separate these two fields are somewhat murky, one general expression that does so is as follows. Differences exist historically about distinguishing between astrobiology and exobiology, so a redefinition is provided here. Astrobiology seeks to find a second genesis of life within our own solar system while exobiology seeks to find it beyond our solar system, the latter of which has become more relevant with the increasing discovery of exoplanets and more recently exomoons. These are by far the most common approaches to the search for extraterrestrial life and they are specialized in the natural and physical sciences rather than the social sciences. Practically, astrobiology tends to be the overarching title for the search for all life.

Nevertheless, as with other issues, there are astrosociological implications involved with the search for extraterrestrial life. The social sciences have taken a back seat, historically, although things are changing and there were always exceptions to this general rule. For example, a NASA publication entitled "Workshop on the Societal Implications of Astrobiology" was published in 2001, which clearly focused on the importance of the social sciences and included social scientists [74]. This provided a bedrock for future off and on collaboration.

However, an academic field dedicated to the focus on the social-scientific implications of the search for extraterrestrial life was needed. "A new discipline dubbed 'astrosociology' has arisen in the past few years that addresses the societal impact of space exploration, including extraterrestrial life [75], p. 174." Thus, there are social

implications of astrobiology [76]. "The social and cultural implications of this [astrosociological] work make it too important to ignore. In fact, it is imperative that astrosociologists participate alongside their space-community counterparts to attain comprehensive knowledge; both for its own sake and for practical application should some type of reaction prove necessary [75], p. 175." This is the case on Mars or wherever a discovery is made.

Exo-astrosociology, which was first introduced by this author, is a recently created astrosociology subfield. It is defined as the study of extraterrestrially-related forms of astrosocial phenomena. It "involves how the very search for extraterrestrial life impacts humanity in a myriad of different ways" and "also involves how ongoing failure and potential success affects societies, cultures, social groups, subcultures, and individuals [77], p. 4." This subfield was finally introduced in order to create a community of like-minded social scientists and a way for astrobiologists to more easily collaborate with them. An exo = astrosociology literature will add a missing component in a more organized fashion than existed before its inception.

Mars is good place for conducting SETI and astrobiological research. Of course, life may well exist on the surface or subsurface of Mars and biosignatures likely exist. The concept of planetary protection, if carried out as conceptualized and described above also makes it possible to conduct research to discover extant and fossilized life. The search for life beyond Mars is also an improvement compared to Earth in some ways. The atmospheric volume is only one-percent of that of Earth's, which provides a good environment for surface-based telescopes when dust storms are not obscuring the view. It is also possible to place telescopes on the moons of Mars, Deimos and/or Phobos. There are several possibilities that require investigation.

Looking for a second genesis on Mars will be a priority for scientists. Where water exists, there could also exist Martian life. The existence of extremophiles on Earth consist of organisms that live in extreme environments such as "(1) in Mono Lake (a highly alkaline environment) (see **Figure** 7), (2) in Yellowstone's Sylvan Springs (sulfuric acid), (3) within caves deep under-ground in harsh conditions, (4) within Antarctic ice sheets (including Lake Vostok), and (5) thriving on highly radioactive control rods in nuclear power plants" [78, pp. 402-403]. Extremophiles on Earth provide optimism that similar extant or fossilized microbes can be discovered on Mars. In fact, the choice to live in lava tubes may bring about objections by astrobiologists and exo-astrosociologists due to the possibility of contaminating life and destroying fossils in these caves. Those searching for life are excited to explore potential nonhuman Martian ecosystems above the surface and below while protecting it from contamination and destruction to the extent possible.

As discussed, water is an important resource to sustain human life as well. Mining will be a priority for others. Water exists at the poles, but it also exists elsewhere at much lower latitudes (see **Figure 8** as an example) [79]. Drilling for water will occur. Putting in place the infrastructures to locate water and transfer it to habitat components is a messy enterprise. Ideally, settlements will be placed relatively close to sources of water. Thus, when humans finally live on Mars, planetary protection will become increasingly difficult, as we have witnessed on Earth when human communities encroach on previously pristine ecosystems. How will competing factions work out this clash of interests? It is important for astrosociologists to be there to study these types of dynamics and perhaps assist in resolving tensions.

17. Space archeology on Mars

Space archeology is defined as the study of human-made items, or material culture, found in space environments (including on Earth) and their relationships

Figure 7.
Mono Lake.

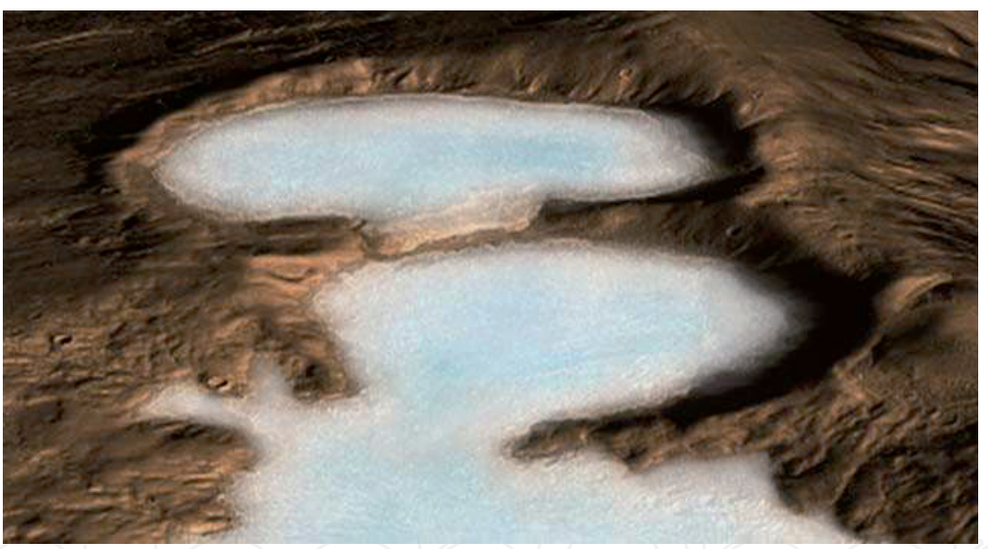

Figure 8.
Artist concept of a glacier on Mars discovered in 2008. Photo credit: NASA/JPL.

to human exploration, which includes efforts to preserve them as cultural heritage [80]. Interestingly, space archeology has only gained acceptance in the last decade or so according to Dr. Alice Gorman [81]. Dr. Gorman and other space archeologists focus on protecting artifacts on the Moon in orbit around the Earth, and material culture on Earth's surface including space debris. Examples include the Apollo 11 site and others visited by humans, rovers, and landers. The same arguments apply to protecting the heritage of sites on Mars as well, and wherever humans leave their material culture. Preserving history for generations represents a laudable goal.

Beyond protection of potential life is that of the material culture, potential monuments, that rest on the Martian surface. These emissaries of humankind include the Viking landers, the Pathfinder lander and Sojourner rover, the Spirit and Opportunity rovers, the Phoenix Science Laboratory, the Curiosity rover (see **Figure 9**), and the InSight lander. Interestingly, the Spirit Rover ended operations on the north face of the Troy plateau in January of 2009. Crash sites could also be of value, as the debris

Figure 9.
Curiosity snaps a belly selfie at Buckskin Mountain base drill site. Photo credit: NASA/JPL.

may finally help determine causes of the failures. One example is the Mars Polar Lander. The Beagle 2 landed successfully and began some preliminary operations, but it shut down and failed to contact Earth. Protection of these historically significant items may seem like an obvious way to handle them, but history has shown that some individuals opt to grab pieces for souvenirs and others simply favor destroying them. Scientists may also abscond with pieces of rovers and other artifacts for analyses of various types. Destruction of artifacts, or at least serious damage to them, is possible or even probable without adequate protections and Martian laws in place.

Legal prohibitions may not allow direct access to heritage sites with some logical exceptions, but adherence to such laws may be unheeded by some settlers. As with other areas of social life, social and behavioral scientists need to study social, cultural, and behavioral patterns that can inform policy makers and law enforcement officials of violations. They can also help to design tourist venues assuming that they are practically accessible by settlers while also being protected. Study of this behavior would also be of value to exo-astrosociologists and therefore the Martian settlement.

18. Interplanetary relations

It cannot be emphasized enough that settlers on Mars (or anywhere off the planet Earth) will adapt to their physical environment within the habitat. They will seek to protect themselves from health and safety risks that impinge on them from the larger environment beyond its walls such as radiation, an altered gravitational field, and the inability to breathe without a spacesuit on the Martian surface. This is because isolation and confinement alone will impact on both physiology and behavior [67]. These factors and several others will cause human populations to adapt to these physical factors, which will result in social forces that will inevitably modify the base culture set up during the planning stages on Earth and that have been modified during the voyage. For the settlement, social and cultural change will continue from the training on Earth to the landing on the Martian surface, and beyond that point [44].

A significant part of this process will alter the culture in ways that eventually cause residents to view themselves as members of the Martian settlement apart

from their identities as humans from terrestrial societies such as the United States or Russia. A socialization process will develop in which a group mentality reinforces their Martian or specific settlement identity over time. For those who stay permanently, this process will occur due to individuals interacting with others around them rather than relying on past memories of their time before settling on Mars.

Dependence on Earth-based governments and private organizations for supplies can take its toll as can difficulties during their interactions. Group cohesion among settlers will develop and increase over time, and ethnocentrism could well result in them thinking of themselves as "different." In such a situation, they will become part of their in-group and Earth dwellers will become the out-group, at least to some extent. At first, settlers will require assistance in many forms including food, water, and other supplies in order to survive. However, to the extent that they can fend for themselves over time and provide goods and services unique to Mars, they may be able to wean themselves off of their dependency from relying on Earth for at least *all* of their requirements.

These processes may take quite a bit of time although we have seen these patterns on Earth in the development of nations, including their realignments and border changes. Changing cultural norms and values can result in dramatic changes of fundamentally held ideas and the resulting changes in behavior. Ideas can forge new social institutions and behavioral patterns of the larger population that can become very different than when the social system started.

Economically, humans have been used to transacting with other Earth-based partners. However, for settlers on Mars, Earth-to-Earth transactions for which they were familiar will have changed to an Earth-to-Mars relationship. In this scenario, the supply run from an Earth-based nation, corporation, or other entity to an extraterrestrial human settlement would change for both those on Earth and those on Mars. For settlers, to the extent that leaders of the Martian settlement perceive they are being mistreated in some ways, this can escalate the path toward separation of the settlement from all forms of Earth-based jurisdictions. They would, in this case, behave in accordance with their own laws.

The process of getting to a point in which this type of relationship between the two planets manifests is theoretically a long one. However, it can be accelerated to the extent that leaders evaluate the situation in a way that they feel being exploited. This becomes a shift to *interplanetary relations* – which is akin to the international relations found on Earth – that takes place between (1) Earth-based governments, non-governmental organizations (NGOs), corporations, and other entities, and (2) a particular Martian settlement.

19. Martian planetary defense

Planetary defense efforts have logically focused on protecting against possible strikes against Earth. Moreover, it has increased in seriousness over the last couple of decades. The B612 Foundation was founded in 2002 to provide a nongovernmental voice focusing on the need to protect Earth from asteroids and comets [82]. Other space advocacy organization such as The Planetary Society [83] and The National Space Society [84] also provide resources and efforts related to improving planetary defense resources and capabilities. NASA has been searching for near Earth Objects (NEOs) since 1998 when Congress first directed it "to find and track 90 percent of NEOs 1 kilometer or more in diameter within 10 years, as objects of this size would cause a global catastrophe [85]." The newly created Space Force is slated to take over the responsibility of finding and cataloging NEOs [86]. In addition to NASA, the European Space Agency (ESA) is also taking part in locating NEOs [87]. The search for threatening asteroids and comets is serious business to

which both public and private entities contribute. Recent activity to protect Earth from a catastrophic event demonstrates how important this issue has become.

If it is serious enough for terrestrial nations to take action, the prospects for other locations in our solar system are even more dire. Both cosmic bodies first to be settled, the Moon and Mars, are more susceptible to asteroid and comet fragment strikes than the Earth due to its much denser atmosphere. While the lunar atmosphere is negligible, the Martian atmosphere does exist though projectiles from space do not burn up as readily as is the case for Earth. Because the Martian atmosphere is so thin as discussed earlier, we know from spacecraft sent there that objects hit hard. "Even though the surface gravity on Mars is only 3.7 meters/sec (compared to 9.8 meters/sec on Earth), the thin atmosphere means that the average terminal velocity hits a nail-biting 1000 km/hour or so, compared to about 200 km/hour back home [86]." While landing on Mars is difficult due to its thin atmosphere, as exemplified by spacecraft having to do a lot of work to shed speed, asteroids and comets do not need to "worry" about that although settlers sure need to worry about being hit at such great speeds (see **Figure 10**).

Thus, based on activities on Earth, the need to keep track of Near Mars Objects (NMOs) is perhaps of greater concern. Mars is a smaller planet, but its atmosphere is much less dense, so a direct strike would be more devastating for an object of the same size. It is important to put things in perspective, however. The chances of a cosmic object striking a settlement is very low. It would increase with a larger perimeter of settlement components, but it would still be very unlikely to occur. Nevertheless, the Martian surface is full of craters caused by strikes from space. Therefore, keeping watch wherever humans reside is a good idea. Earthlings do it from their home planet and aboard the International Space Station (ISS). Infrastructure to deal with possible comet or asteroid strikes would need to be constructed as part of the settlement. Telescopes orbiting Mars, perhaps on one or both of its moons, or in nearby space, would mimic what humans do, or will do, on Earth.

As on Earth, this authored has proposed that there are three main phases related to coping with the possibility of an asteroid or comet strike: (1) detection, (2) defense, and (3) survival [88] (see **Table 1** for details). The detection and defense components of the planetary defense strategy are quite obvious and they receive by far the most coverage by scientists the information media, social media, and entertainment outlets. A potential strike of Earth is much more

Figure 10.
Artist illustration of an object striking Mars/photo credit: Don Dixon.

(1) Detection	This component of the strategy involves the detection of possible Mars-bound asteroids and comets in orbits and trajectories that threaten to collide with Mars.
(2) Defense	Once a threat is verified to be on a collision course with Mars and a potential threat to a Martian settlement, either directly or indirectly, this component involves eliminating the threat using whatever means are available.
(3) Survival	Should the second component fail on a partial or complete basis, this component involves moving people and vital resources (if possible) to safer places such as lava tubes.

Table 1.
Summaries of the three components of the planetary defense strategy (modified from Pass [88], p. 8).

serious than a Martian threat due to the population differences although either scenario could be catastrophic.

Even though the threat is less likely to threaten a Martian settlement, the possibility still exists. What happens if the defense efforts fail? In such a case, if the population is endangered, the survival of the settlers becomes the priority. Moving people to a safer area is easier because the population is relatively small compared to Earth and the unpopulated areas are vast. The problem that does exist is that individuals would need to be suited up in order to survive outside. Rovers could provide much needed methods of escape. As on Earth, preplanning to better cope with such a disastrous scenario is the optimal course of action.

20. Conclusions

Too many important astrosociological issues exist to cover in a single chapter, although many are found here, which has resulted in cursory coverage of some areas. It does demonstrate, however, how many issues require astrosociological research so much more astrosociological research is needed. This means that many more trained astrosociologists must exist to accomplish it. This will require a substantial increase in astrosociology education that will, in turn, result in an increase in related research. While an astrosociology course is being taught at Harvard University, it is imperative for astrosociological education to spread throughout academia in order to settle Mars successfully. ARI's "Astrosociology in the Classroom" program is important for a number of other reasons as well. This discussion about a hypothetical Mars settlement demonstrates the fact that too little knowledge currently exists.

Thus, while it is true that no human has yet landed on the Martian surface, it is not too early to think about it and study these types of astrosociological issues because the underpinnings of planning for a Martian settlement already exist and they are becoming increasingly prevalent. The movement of lunar and Martian human exploration and permanent settlement has spread to the private sector with the advent of NewSpace companies and nonprofit organizations. Space advocacy groups proliferate. Progress in support of space exploration continues. In order to further this movement, more space professionals and students versed in both the physical and social sciences need to access their astrosociological imagination. They need to understand the true impact of astrosocial phenomena in their lives and in their societies. Only then will they better recognize the value of working together rather than separately as they have too often in the past.

Many complex issues are discussed in this chapter. Planning for all three stages (i.e., on Earth before launch, during the transit phase, and once arriving at Mars) represents a crucial approach that must involve all types of scientists and scholars who are relevant contributors to space exploration and living in isolated and confined

spaces. There are both physical and social environments that involve architecture and art, cultural considerations, and the construction of social institutions beyond construction of spacecraft and habitat components. Deviance and other social problems will manifest on a continuing basis that will require astrosociological research and intervention. Other areas relevant to settling on Mars that are covered here include medical astrosociology, space law to Martian law, planetary protection, exo-astrosociology, space archeology, interplanetary relations, and Martian planetary defense.

All of these space-related social-scientific issues – astrosocial phenomena – reflect a type of inquiry that requires significantly greater attention by social scientists. The hope here is that these issues are brought to the forefront so that future Martian settlements are successfully constructed and that the social systems in which their citizens live can thrive beyond simple survival, whether they become realities in 10 years or further down the line. Otherwise, rejecting astrosociology on Mars will result in hardships and social problems that could have been avoided or at least greatly mitigated by astrosociologists.

The Astrosociology Research Institute exists to make astrosociology on Mars possible. As emphasized throughout this chapter, the settling of Mars involves many issues that transcend those covered by STEM disciplines and fields alone. Astrosocial phenomena include realities that focus on the human dimension, which goes beyond the concerns of physical and natural scientists. However, these individuals often make remarks about social, cultural, behavioral, and psychological issues. At the same time, most of them have not studied these types of issues in any great detail although it demonstrates the connection between the physical and social sciences. These types of scientists as well as humanities scholars and artists are needed because they are trained in these subjects. Together, when they collaborate, they can provide expertise from both branches of science to elicit insights that neither side alone can produce. As **Figure 11** illustrates, astrosociology is a multidisciplinary, collaborative scientific field, and convergence among all relevant disciplines and fields represents a major objective that is currently on the path to significant realization.

It is unwise for planners of a Martian settlement to move forward without social-scientific input, if individuals visit the settlement as tourists and especially if they commit to staying permanently. There are too many statuses and roles that need to depend on one another, which means that planners must focus on the intricacies

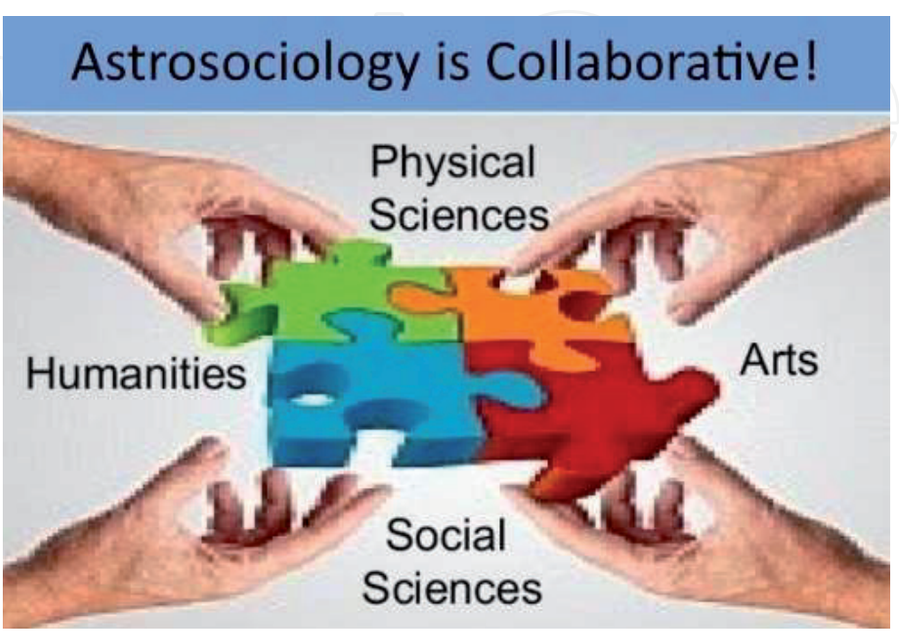

Figure 11.
Astrosociology is a multidisciplinary academic field.

involving constructing a functional social system—especially as its population grows—just as the greatest attention is traditionally paid to the construction of physical assets such as rockets and the habitats and their systems. Like the engineering systems in a spacecraft, for example, a Martian city or smaller settlement, possesses its own intricate systems in the form of human relationships. The latter is more difficult to plan for and keep functioning in a positive way because the components, in this case humans, keep changing unlike what occurs to the same extent in physical systems.

So, while rocket science can get people to Mars and engineering can keep the habitat functioning, it cannot ensure societal success within the habitat. The crux of the matter boils down to one question. What will happen to human life if astrosociology fails to get to Mars? Without a semblance of social order and cultural consistency, rocket scientists or mathematicians can do very little to construct a stable Martian society. Both branches of science must work together. Only cooperation and collaboration between those in both branches can result in a successful outcome on a sustainable basis. Physical and social systems must work together, as they are complementary, and that requires physical and social scientists to work together.

This chapter has focused on some of the major issues relating to Martian settlements, and perhaps some of them are not frequently discussed as part of this larger theme, but it will be the first location to be settled beyond the cislunar environment and it is important to expand our astrosociological imagination beyond what is common. Moreover, the difficulties of humans seeking to settle in other space environments will only become more pronounced the farther away from Earth that they migrate. Social life will become increasingly difficult in a number of social, cultural, and psychological dimensions. If human settlements can successfully transform themselves into well-functioning space societies, they will provide those who migrate beyond Mars with invaluable lessons of survival. Additionally, the social problems and failures that become documented will also provide these intrepid settlers with lessons of what to avoid if possible. Thus, it is important for astrosociologists to be among the settlers in order to monitor, document, and support social life in Martian settlements and beyond.

It is not logical to exclude those trained in the social sciences. They are important on Earth, so why would they be less so on a planet inhospitable to human life, which challenge settlers socially, culturally, and psychologically? They are important wherever humans reside, whether here on Earth or beyond. Astrosociology on Mars makes logical sense because astrosociology on Earth is also invaluable to human societies and their citizens because they offer complementary insights to those in the physical and natural sciences who traditionally study space settlement issues.

Thanks

I would like to thank two late individuals who inspired me, Dr. Allen M. Tough (1936–2012) and Dr. Albert A. Harrison (1940–2015), as a reminder to all those who support astrosociology. Allen Tough was a futurist and SETI scholar who mentioned the term "astrosociology" as a possible new social science field in an article that prompted me to found the field immediately after reading it [26]. I met him one time in person at a conference and he encouraged me to continue my efforts. Albert A. Harrison was a social psychologist who I met online initially after reading one of his books [27]. He became a friend and the first advisor to The Astrosociology Research Institute. He attended several conferences with me and we cowrote a few publications. His early inspiration in 2005 helped me greatly to carry on when things were not always easy. These two individuals inspired me the most when I decided to found astrosociology in 2004.

I would also like to thank Dr. Thomas Gangale and the late Dr. Marilyn Dudley-Rowley who I met in 2004 at a sociology conference. They were early supporters and participants in astrosociological efforts including helping me to found The Astrosociology Research Institute. I also wish to thank Dr. Gangale for creating ARI's logo (see **Figure 2**).

Author details

Jim Pass†
The Astrosociology Research Institute, Huntington Beach, CA, USA

*Address all correspondence to: jpass@astrosociology.org

† This author is also available on Twitter (twitter.com/astrosociology), Facebook (facebook.com/jimpass2), and LinkedIn (linkedin.com/in/jimpass/).

References

[1] Pass J. Astrosociology: Exploring the human dimension of outer space. Ad Astra. 2019;**3**:43-44

[2] Why Social Science? Because We Will Need to Do Better in the Next Crisis. Available from: https://www.whysocialscience.com/

[3] Pass J, Harrison AA. Chapter 38: Astrosociology (social science of space exploration). In: Bainbridge WS, Roco MC, editors. Handbook of Science and Technology Convergence. New York: Springer; 2016. pp. 545-558

[4] Pass J. Astrosociology, education and the future of space exploration, exploitation, and settlement. In: Paper Presented at the AIAA Space Aeronautics Forum and Exposition. Paper Written for the Society and Space Session for the AIAA Space Conference and Exposition; 12-14 September 2017; Orlando, FL. 2017. p. 2. Available from: http://www.astrosociology.org/Library/PDF/Space2017-Pass-AstrosociologyEdAndFuture.pdf

[5] Pass J. Target viewpoint: Examining the definition of astrosociology. Astropolitics. 2011;**9**(1):6-27

[6] Peters MA. Beyond Earth's globalization: Sociology of outer space? Review of Contemporary Philosophy. 2017;**16**:83-91

[7] Pass J. Inaugural Essay: The Definition and Relevance of Astrosociology in the Twenty-First Century (Part One: Definition, Theory and Scope). 2004. Available from: http://www.astrosociology.org/Library/Iessay/iessay_p1.pdf

[8] Pass J. Space: Sociology's forsaken frontier. In: Presented at the California Sociological Association (CSA) Conference; 16 October 2004; Riverside, CA. Available from: http://www.astrosociology.org/Library/PDF/submissions/Space_Sociology%27s%20Forsaken%20Frontier.pdf

[9] Finney BR. From Sea to Space (The Macmillan Brown Lectures, 1989). Honolulu: University of Hawaii Press; 1992

[10] McKay CP. What is life – And when do we search for it on other worlds? Astrobiology. 2020;**20**:163-166

[11] Boston P. The Case for Mars: Proceeding of a Conference Held 29 April-2 May 1981 at the University of Colorado, Boulder (Science and Technology Series). American Astronautical Society; 1984

[12] Shostak S. Introduction: The true nature of aliens. International Journal of Astrobiology. 2018;**17**(4):281

[13] Harrison AA, Clearwater YA, McKay CP, editors (Forward by Gunderson EKE). From Antarctica to Outer Space: Life in Isolation and Confinement. New York: John Wiley & Sons, Ltd.; 1989

[14] Finney BR, Jones EM. Interstellar Migration and the Human Experience. Berkeley: University of California Press; 1985

[15] Swenson LS Jr, Grimwood JM, Alexander CC. This New Ocean: A History of Project Mercury. Washington, DC: National Aeronautics and Space Administration (NASA); 1998

[16] Kanas N. Humans in Space: The Psychological Hurdles. Springer Praxis Books; 2015

[17] Vakoch DA, editor. Psychology of Space Exploration: Contemporary Research in Historical Perspective. Washington, DC: National Aeronautics and Space Administration (NASA); 2019

[18] McCurdy HE. Space and the American Imagination. Baltimore: John Hopkins University Press; 1997

[19] Launius RD. Frontiers of Space Exploration. 2nd ed. Westport, CT: Greenwood; 2004

[20] Logsdon JM, John F. Kennedy and the Race to the Moon (Palgrave Studies in the History of Science and Technology). London: Palgrave Macmillan; 2011

[21] McCurdy HE. Financing the New Space Industry: Breaking Free of Gravity and Government Support (Palgrave Studies in the History of Science and Technology). New York: Palgrave Pivot; 2019

[22] Finney B. Lunar base: Learning to live in space. In: Mendell WW, editor. Lunar Bases and Space Activities of the 21st Century. Washington, DC: National Academy of Sciences; 1984. pp. 751-756

[23] Bluth BJ. Lunar settlements: A socio-economic outlook. Acta Astronautica. 1988;**17**(7):659-667

[24] Harris PR. Behavioral science space contributions. Behavioral Science. 1989;**34**(3):207-227

[25] Rudoff A. Societies in Space (American University Studies, Series XI, Anthropology & Sociology. Vol. 69). New York: Peter Lang Publishing; 1996. p. 75

[26] Tough A. Positive consequences of SETI before detection. *Acta Astronautica*. 1998;**42**(10-12):745-748

[27] Harrison AA. Spacefaring: The Human Dimension. Berkeley, CA: University of California Press; 2001

[28] Dudley-Rowley M. The great divide: Sociology and aerospace. In: Paper Presented as Part of the Special Dedicated Session Entitled "Astrosociology: The Establishment of a New Subfield" at the California Sociological Association (CSA) Conference; 16 October 2004; Riverside, CA. 2004. Available from: http://www.astrosociology.org/Library/PDF/submissions/The%20Great%20Divide_CSA2004.pdf

[29] Sadeh E. Chapter 8: Impacts of the Apollo program on NASA, the space community, and society. In: Dick SJ, editor. Historical Studies in the Societal Impact of Spaceflight. Washington, DC: National Aeronautics and Space Administration (NASA) History Program Office; 2006. pp. 491-534. Available from: http://www.astrosociology.org/Library/PDF/Historical-Studies-Societal-Impact-Spaceflight.pdf

[30] Gangale T. Common heritage in magnificent desolation. In: Paper Presented as Part of a Session Entitled "Astrosociological Perspective on Space Exploration" at the AIAA Aerospace Sciences Meeting and Exhibit (ASM 2008) Conference; 8 January 2008; Reno, NV. 2008. Available from: http://www.astrosociology.org/Library/PDF/ASM2008_MagnificentDesolation.pdf

[31] Lockard ES. Symbiocracy: The structuring of new societies in space based on principles of mutualism and symbiotization. In: Paper Presented as Part of a Session Entitled "Astrosociological Perspectives on Space Societies" at the AIAA Space 2008 Conference; 10 September 2008; San Diego, CA. 2008. Available from: http://www.astrosociology.org/Library/PDF/Lockard_Symbiocracy.pdf

[32] Bainbridge WS. Virtual world astrosociology. In: Proceedings of the 2nd Symposium on Astrosociology that was part of the Space Propulsion and Energy Sciences International Forum (SPESIF) Held at the Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland. The session was called "Overview Effect". American Institute of Physics; 2010. Available

from: http://www.astrosociology.org/Library/PDF/SPESIF2010_Bainbridge_VirtualWorld.pdf

[33] Hearsey CM. The nexus between law and astrosociology. Astropolitics. 2011;**9**(1):1-5

[34] Lempert D. Living in space: Cultural and social dynamics, opportunities, and challenges in permanent space habitats. Astropolitics. 2011;**9**(1):84-111

[35] Pop V. Space exploration and folk beliefs on climate change. Astropolitics. 2011;**9**(1):50-62

[36] Dator JA. Social Foundations of Human Space Exploration (SpringerBriefs in Space Development). Cham, Switzerland: Springer International Publishing; 2012

[37] Oman-Reagan M. Space exploration and planetary perspectives. In: Schultz EA, Lavenda RH, Dods RR, editors. Cultural Anthropology: A Perspective on the Human Condition. 4th Canadian ed. Canada: Oxford University Press; 2018. pp. 296-297

[38] Wood J, Schmitt L, Lugg D, Ayton J, Phillips T, Shepanek M. Life, survival, and behavioral health in small closed communities: 10 years of studying isolated Antarctic groups. Aviation, Space, and Environmental Medicine. 2005;**76**(Supplement 1):B89-B93

[39] Kanas N. Chapter 3: Psychosocial value of space simulation for extended spaceflight. In: Bonting SL, editor. Advances in Biology and Medicine. Vol. 6. 1997. pp. 81-91

[40] Palinkas LA. Psychosocial issues in long-term space flight: Overview. In: Gravitational and Space Biology Bulletin. 2001;**14**(2):25-33

[41] Tachibana K. A Hobbesian qualm with space settlement. Futures. 2019;**110**:28-30

[42] Mills CW. The Sociological Imagination. New York: Oxford University Press; 1959. p. 6

[43] Pass J. Albert A. Harrison: Outer space, the human dimension, and astrosociology. In: Paper Presented in the Society and Space Session at the AIAA Space Conference; 13-16 September 2016; Long Beach, CA. 2016. p. 4. Available from: http://www.astrosociology.org/Library/PDF/Space2016-JPass-AlbertAHarrison.pdf

[44] Pass J. Astrosociology and the planning of space ecosystems. In: Paper Presented as Part of the Space and Society Session at the Space 2015 Conference; September 2015; Pasadena, CA. 2015. Available from: http://www.astrosociology.org/Library/PDF/Space2015--JPass-PlanningSpaceEcosystems.pdf

[45] Hancock PA. On bored to Mars. The Journal of Astrosociology. 2017;**2**:103-120

[46] Blackwell-Landon L, Slack KJ, Barrett JD. Teamwork and collaboration in long-duration space missions: Going to extremes. American Psychologist. 2018;**73**(4):563-575

[47] Pass J. The astrosociology of space colonies: Or the social construction of societies in space. In: Space Technology and Applications International Forum (STAIF) Conference Proceedings. Paper Published in Proceedings and Presentation at 2006 STAIF Conference; Albuquerque, NM. Vol. 813. American Institute of Physics (AIP); 2006. pp. 1153-1161. Available from: http://www.astrosociology.org/Library/PDF/submissions/STAIF_Astrosociology%20of%20Space%20ColoniesPDF.pdf

[48] Pass J. Chapter 9: An astrosociological perspective on the societal impact of spaceflight. In: Dick SJ, editor. Historical Studies in the Societal Impact of Spaceflight.

Washington, DC: National Aeronautics and Space Administration (NASA) History Program Office; 2015. p. 554. Available from: http://www.astrosociology.org/Library/PDF/Historical-Studies-Societal-Impact-Spaceflight.pdf

[49] Lee P. Habitability of lava tubes on the Moon and Mars: Lessons from Earth. In: Final Summary to 2018 MBR Space Settlement Challenge. Dubai Future Foundation; 2019. Available from: Guaana.com; https://digital.lib.usf.edu/content/SF/S0/07/02/37/00001/K26-05529-PascalLEE-MBRSSC-Guaana-Final_Summary-20190128-A-Compressed.pdf

[50] Sherwood B. Organizing ourselves: Schema to build the international space architecture community. In: AIAA Space Conference and Exposition; San Jose, CA (AIAA 2006-7471). 2006

[51] Harrison AA. Humanizing outer space: Architecture, habitability, and behavioral health. Acta Astronautica. 2010;**66**(5-6):890-896

[52] Pletser V, Zubrin R, Quinn K. Simulation of Martian EVA at the Mars Society Arctic Research Station. In: 53rd International Astronautical Congress, The World Congress; 10-19 October 2002; Houston, TX. 2002. pp. 1-11

[53] Durão MJ. Embodied space: A sensorial approach to spatial experience. In: Proceedings at the First Symposium of Astrosociology That Was Part of the Space Propulsion, and Energy Sciences International Forum Held in Huntsville, Alabama. The Session Was Called "Space Societies: The Settlement of Space Environments". 2009. p. 399. Available from: http://www.astrosociology.org/Library/PDF/Durao_SPESIF2009.pdf

[54] Durkheim E. The Division of Labor in Society (Translated by G. Simpson). New York: The Free Press; 1964

[55] Rainer E. Chapter 5: Projecting landscapes of the human mind onto another world: Changing faces of an imaginary Mars. In: Geppert ACT, editor. Imagining Outer Space: European Astroculture in the Twentieth Century. London: Palgrave Macmillan; 2012. pp. 89-105

[56] Bierstedt R. The Social Order. 3rd ed. New York: McGraw-Hill, Inc.; 1970

[57] Pass J. Deviance in space habitats: A preliminary look at health and safety violations. *Physics Procedia*. 2011;**20**:353-368. Paper Published in Proceedings at the 3rd Symposium of Astrosociology That Was Part of the Space Propulsion, and Energy Sciences International Forum (SPESIF) Held at the University of Maryland, College Park. The Session Was Called "Medical Astrosociology." Available from: http://www.astrosociology.org/Library/PDF/SPESIF2011--Deviance-in-Space-Habitats.pdf

[58] Ambrosius JD. Our cosmic future? How religion might shape it. In: Levinson P, Waltemathe M, editors. Touching the Face of the Cosmos: On the Interaction of Space Travel and Religion. New York: Fordham University Press. p. 28

[59] Pass J. Medical astrosociology: Ethical dilemmas in space environments. In: Paper Presented as Part of an Astrosociology Session at the AIAA Space 2009 Conference; 20 September 2009; Pasadena, CA. 2009. Available from: http://www.astrosociology.org/Library/PDF/Pass_EthicalDilemmas.pdf

[60] Stoner I. Humans should not colonize Mars. Journal of the American Philosophical Association. 2017;**3**(3):334-353

[61] Slobodian RE. Selling space colonization and immorality: A psychosocial, anthropological critique

of the rush to colonize Mars. Acta Astronautica. 2015;**113**:89-104

[62] Marino L. Humanity is not prepared to colonize Mars. Futures. 2019;**110**:15-18

[63] Pass J. Chapter 9: Astrosociology: Social problems on Earth and in outer space. In: Treviño AJ, editor. The Cambridge Handbook of Social Problems. Vol. 1. New York: Cambridge University Press; 2018. pp. 149-166

[64] Pool SL, Davis JR. Space medicine roots: A historical perspective for the current direction. Aviation, Space, and Environmental Medicine. 2007;**78**(Supplement 1):A3-A4

[65] NASA's Twins Study Results Published in Science Journal. 2019. Available from: https://www.nasa.gov/feature/nasa-s-twins-study-results-published-in-science/

[66] Pass J. Space medicine: Medical astrosociology in the sickbay. In: Paper Presented as Part of a Session Entitled "Astrosociological Perspective on Space Exploration" at the AIAA Aerospace Science Meeting and Exhibit (ASM 2008) Conference; 8 January 2008; Reno, NV. 2008. Available from: http://www.astrosociology.org/Library/PDF/ASM2008_MedicalAstrosociology.pdf

[67] NASA Human Research Program. Available from: https://www.nasa.gov/hrp/about

[68] Sipes WE, Polk JD, Beven G, Shepanek M. Behavioral health and performance. In: Nicogossian A, Williams R, Huntoon C, Doarn C, Polk J, Schneider V, editors. Space Physiology and Medicine. New York: Springer; 2016. p. 2016

[69] Miquel J, Economos AC. Space gerontology. NASA conference publication 2248. In: Proceedings Held at NASA Ames Research Center; 30-31 January 1978; Moffett Field, CA. Washington, DC: NASA;

[70] Hearsey CM. The nexus between law and astrosociology. Astropolitics. 2011;**9**(1):3

[71] Harrison AA. Overcoming the image of little green men: Astrosociology and SETI. In: Paper Presented as Part of a Dedicated Session Entitled "Astrosociology: The Sociology of Outer Space," at the California Sociological Association (CSA) Conference; 11 November 2005; Sacramento, CA. 2005 Available from: http://www.astrosociology.org/Library/PDF/submissions/Overcoming%20LGM_Harrison.pdf

[72] Montgomery L. Opportunities of first impression and the outer space treaty. Astrosociological Insights. 2017;**6**(1):8-10

[73] NASA, Office of Safety and Mission Assurance (OSMA). Available from: https://sma.nasa.gov/sma-disciplines/planetary-protection

[74] Harrison AA, Connell K, editors. Workshop on the Societal Implications of Astrobiology: Final Report, Ames Research Center: NASA Technical Memorandum. 2001. Available from: http://astrobiology.arc.nasa.gov/workshops/societal/societal_report.pdf; http://www.astrosociology.org/Library/PDF/NASA-Workshop-Report-Societal-Implications-of-Astrobiology.pdf

[75] Dick SJ. Astrobiology, Discovery, and Societal Impact. Cambridge, England: Cambridge University Press; 2018. p. 174

[76] Dick SJ. Analogy and the societal implications of astrobiology. Astropolitics. 2014;**12**(2-3):210-230

[77] Pass J. Exo-astrosociology and the search for technosignatures. In: Paper Presented as Part of the Society

and Aerospace Technology Session at the AIAA SciTech 2019 Conference; 9 January 2019; San Diego, CA. 2019. Available from: http://www.astrosociology.org/Library/PDF/JPass--Exo-AstrosociologyAndTechnosignatures.pdf

[78] Pass J. Astrosociology implications of astrobiology (revisited). In: Proceedings at the 2nd Symposium on Astrosociology that Was Part of the Space Proposition, and Energy International Forum (SPESIF) Held at the Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland. The session was called Astrosociology and Astrobiology (and SETI). American Institute of Physics (AIP) Proceedings. Vol. 1208. 2010. pp. 402-417. Available from: http://astrosociology.org/Library/PDF/SPESIF2010_Pass_Astrobiology.pdf

[79] NASA Spacecraft Detects Buried Glaciers on Mars. 2008. Available from: https://www.nasa.gov/mission_pages/MRO/news/mro-20081120.html#:~:text=%2D%20NASA's%20Mars%20Reconnaissance%20Orbiter%20has,identified%20on%20the%20Red%20Planet.&text=This%20discovery%20is%20similar%20to-,under%20rocky%20coverings%20in%20Antarctica

[80] Capelotti PJ. Space: The [archaeological] frontier. Archaeology. 2004;57(6):46-51

[81] Gorman A. We Need to Protect the Heritage of the Apollo Missions. 2009. Available from: theconversation.com; https://theconversation.com/we-need-to-protect-the-heritage-of-the-apollo-missions-117007

[82] B612. Available from: https://b612foundation.org/

[83] The Planetary Society Planetary Defense. Available from: https://www.planetary.org/explore/projects/planetary-defense/

[84] Planetary Defense. The National Space Society. Available from: https://space.nss.org/planetary-defense/

[85] Smith M. NASA and the Space Force to Work Together on Planetary Defense, Space Policy Online.com. 2020. Available from: https://spacepolicyonline.com/news/nasa-and-space-force-to-work-together-on-planetary-defense/

[86] NASA and the Space Force to Work Together on Planetary Defense. Place Policy Online. 2020. Available from: https://spacepolicyonline.com/news/nasa-and-space-force-to-work-together-on-planetary-defense/#:~:text=NASA%20and%20the%20new%20U.S.,comets%20%E2%80%94%20that%20may%20threaten%20Earth.&text=A%20collision%20with%20a%20NEO,are%20likely%20to%20impact%20Earth

[87] ESA Safety and Security Planetary Defence. Available from: https://www.esa.int/Safety_Security/Planetary_Defence

[88] Pass J. Applied astrosociology: The new imperative to protect the Earth and human societies. In: Paper Presented as Part of a Session Entitled "The Astrosociology of Space Colonization" at the AIAA Space 2006 Conference; 20 September 2006; San Jose, CA. 2006. Available from: http://www.astrosociology.org/Library/PDF/Protecting%20Societies.pdf