46th AIAA Aerospace Sciences Meeting and Exhibit
7 - 10 January 2008, Reno, Nevada

AIAA 2008-1465

Space Medicine: *Medical Astrosociology* in the Sickbay

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[Abstract]. As human beings increasingly participate in outer space through their efforts dedicated to exploration, habitation, recreation, and exploitation of resources – in terms of the frequency of missions, the distance travelled, and the number of human beings participating – the importance of coping with their health needs will increase proportionally. The space environment exposes the human body to forces not experienced on the Earth. Examples include variable gravity fields and high radiation levels. We will need to focus more on space medicine and its implications. Even now, plans for professional astronauts to live and work on the Moon and eventually on Mars make medical issues more important than ever within the space community. More needs to be investigated about microgravity and its effects on the human body since long-duration space exploration presents the issue of long-term exposure to weightless conditions and harmful radiation. Additionally, it will become more important to society in general terms due to the growing need to educate and train physicians specializing in space and extreme environmental medicine – as well as astrosociologists who will specialize in these areas for reasons that transcend pure biology. For example, a great many of these implications involve ethnical questions related to risk, the acceptable allocation of resources, and other issues touching on social, cultural, psychological, and psychosocial considerations. In this context, astrosociology becomes relevant. Herein, the author preliminarily discusses some of the significant issues from an astrosociological (or multidisciplinary social-scientific) perspective. The time is now right for bringing in astrosociological issues, as their relevance will only increase with time. Planners within the space community need to take heed of them in order to make informed decisions impossible from strictly a *status quo* biomedical perspective. They will need to collaborate with scientists specializing in *medical astrosociology*.

I. Introduction

WHAT is space medicine, a natural science or a social science? The answer will probably surprise many in the space community. Traditionally, space medicine has been treated almost exclusively as a natural science – that is, a biomedical field. In contrast, medicine on Earth has evolved with both natural science *and* social science components! The reason for this relates to the fact that biomedical issues do not operate in a vacuum but within the context of social groups and society. In fact, medical sociology is a large and popular subdiscipline. Medical anthropology developed as well. Furthermore, social epidemiology has developed within the medical community as well as a component of a medical sociological approach. If developments on Earth serve as the proper model, then space medicine must more strongly incorporate input from the social sciences in a similar manner. This article provides arguments to support this parallel development in the area of space medicine. It provides a presentation of the groundwork favorable to the formal development of a new field called "medical astrosociology."

1. Space Societies Will Replicate Terrestrial Societies

On the Earth, issues such as euthanasia (i.e., assisted suicide or mercy killing), inequality in healthcare, and treatment options involve ethical decisions based on the values of a society's larger culture or those of a subculture. In space, these issues will not disappear. On the Earth, the poor cannot afford the same level of care as more wealthy U.S. citizens. The situations in space will prove even more problematic, especially for small and/or poorly financed missions, as they will need to develop ethical standards that weigh the cost of a given procedure or treatment regimen for one person against the existing resources and the need to service the entire population. In more extreme circumstances, a system of differential social values among different subcultures may develop that place the

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standard of care in a precarious position. Decisions that question medical policy in terrestrial societies are often decided by judges in courtroom proceedings. The same can be expected in a "space society" (i.e., space colony or space settlement) – especially as time unfolds, institutions develop, and the population divides itself into subcultures.[1,2] In the beginning, at least, individuals and groups will bring with them their varied cultural baggage. Their closely-held norms and values will prove difficult to overcome in many circumstances, so this differential system of social values requires consideration, as it will complicate the administration of medical care. One potential solution to this problem involves incorporating a resocialization program into the training process so that all participants share the same cultural values and norms before departure.

In larger "space society" settings, the ability to institute, and the favorable attitude toward, a development of a greater level of care will probably increase over time. In order to provide a similar model for space medicine as exists for terrestrial medicine, or to construct a hybrid system that incorporates the "best" features of several terrestrial systems, the specialization to be known as *medical astrosociology* will need to fill the void dealing with social, cultural, and ethical issues related to space medicine. It will also focus on the psychological and psychosocial issues that relate to space medicine, as psychological problems of individuals often become social problems for society. It will matter little if the society resides on Earth or beyond it, as medical care and delivery consists of both (1) biomedical issues *and* (2) social, cultural, psychological, social psychological and psychosocial issues – the latter of which are hereafter designated as *social-scientific* factors for the sake of brevity.

2. Importance of Expanding Tradition

Humans will soon begin to live in, and visit, space environments featuring various conditions that vary from terrestrial conditions in their own unique ways. If one considers only the gravity field, humans will first experience microgravity in low Earth orbit (LEO), approximately1/6g on the Moon and 1/3g on Mars. The physiological and medical consequences of long-term exposure to these reduced gravity fields remain largely unknown. We have some experience and related data regarding the impact of microgravity on a relatively short-term basis, and very limited data on short-term sojourns to the Moon, but Mars represents a totally unknown scenario. Is a partial gravity field enough to offset the problems experienced in microgravity on a sustained or permanent basis? If so, how much gravity is required? We must come to grips with the possibility that a branch of the human species may evolve into something different than we witness on Earth. Moreover, each gravity field may produce a different overall outcome. These are just some of the issues that practitioners of medical astrosociology must consider, with a special emphasis on how these differences become socially defined by the various categories of human beings. How do the various types of stressors on human physiology affect human behavior on psychological, social psychological, cultural, and social levels? How will humans cope with these changes? These types of issues are vital to the success of medium- to long-term missions[3], especially permanent settlement situations.

With only approximately 450 human beings having travelled into space, and no social group consisting of more than three individuals having lived away from Earth for a sustained period, it seems quite obvious that we know very little about how human beings will respond to space environments in terms of biomedical, physiological, social, cultural, psychological, social psychological, and psychosocial dimensions. We need to involve social scientists in the study of these issues – after all, they are already educated to do this type of work! The social-scientific component opens up new avenues of investigation that will prove invaluable to the success or failure of a sustained human presence in outer space.

The largely neglected dimensions discussed in this introduction will become more critical as human beings venture into space in greater numbers and for longer periods of time. Much of the information presented here brings together important matters from several social-scientific perspectives. One of the major advantages of astrosociology as a multidisciplinary field relates to its ability to combine knowledge in new ways impossible by any one discipline alone. The purpose of this article is to bring attention to many of the major issues associated with astrosociology – specifically, to introduce *medical astrosociology* to the space community – so that those interested in the study of space issues can begin to ponder all of the ramifications of a larger human presence beyond Earth utilizing a more holistic approach.

A. Definition of Space Medicine in an Astrosociological Context

The standard definition of *space medicine* found is something like "the branch of medicine dealing with the effects of spaceflight on the human body." Some medical dictionaries, for example, provide more details as follows: space medicine is "the medical science that is concerned with the biological, physiological, and psychological effects of space flight on humans." This latter definition is consistent with the history of spaceflight in the United States and the Soviet Union/Russia in terms of their inclusion of psychological variables. However, many definitions leave out the "psychological effects" and emphasize only the biological and physiological effects. In contrast, sociological variables rarely receive consideration at all. Because NASA and other organizations – both public and

private – have begun to consider expeditions and bases on the Moon and Mars, now is a prudent time to begin building a knowledge base that prepares humanity for living in space societies and conducting long-duration space missions, including multigenerational ones. This will require a formal expansion of normative practice.

The general argument provided in this article is that space medicine requires another complementary dimension in order to understand all of the essential concepts adequately. Just as with other aspects of astrosociology, the space community cannot hope to explore space successfully without input from the social sciences. In the area of space medicine, then, a focus on biology and physiology alone misses the social dimension that includes ethics and social inequality. In an astrosociological context, space medicine represents one side of a single coin on which medical astrosociology exists on the other side. The two brought together create a complete perspective in space research, just as terrestrial medicine and medical sociology belong together on Earth. Long-duration spaceflight crews and members of space societies will require a coverage of issues that transcends each of the physical and social dimensions alone. Additional contributions from psychology as well as the other social/behavioral sciences and humanities will prove invaluable.[4] A good example of this in addition to medical sociology is *medical anthropology* which focuses on social/cultural beliefs and behaviors that relate to health and health care practice. Medical astrosociology turns the attention of those interested in space medicine from a social-scientific perspective to a single new specialization.

B. Definition of Medical Astrosociology

Among other things, astrosociology examines the relationship between outer space and society. In the case of medical astrosociology, the focus turns to medical social structures and behavioral patterns related to outer space. In this context, it focuses on how social values (important ideas) and their associated norms (rules of behavior intended to protect those ideas) create medical standards for space medicine. These standards will vary from one "space society" to the next, just as they do among terrestrial societies. However, they dictate what actions should be taken, or at least which issues should go into a decision making process, when a medical emergency or less serious situation arises. Restated, the culture of a particular space society provides guidelines to regulate behavior and decision making processes associated with medical issues. Medical policies reflect social values and are protected by social norms. Moreover, social conflict may arise if two or more subcultures oppose values and decisions reflected in the larger culture or among themselves.

This article offers theoreticians and researchers the opportunity to pursue a new specialization of astrosociology called *medical astrosociology*, defined as the study of social and cultural patterns (i.e., astrosocial phenomena) that affect medical issues in space environments. As will become clear, it an approach that combines issues related to space medicine with social-scientific concerns. It may be termed "the space variant of medical sociology" because it borrows concepts primarily related to sociology, psychology, and anthropology impact on medicine and medical practice. It combines space medicine and a social-scientific approach in many ways, many of which currently remain beyond our knowledge. In the future, it would not be surprising to witness medical astrosociology become subsumed under sociology, psychology, and anthropology programs on the one hand *and* space medicine programs on the other hand.

Because space psychology already exists, it is also important to reemphasize that psychological effects have social and cultural consequences. In other words, patterns of behavior that exist at the micro level of analysis, or the level of intimate social interaction, form larger patterns commonly known as rates. Psychological issues become expressed as behavior at the micro level. Once rates become recognized, such as the homicide rate for example, then public and private organizations of varying types normally respond. Rates of disease contraction are much the same. Both examples can result in behavioral changes in the population. In a space society, with a limited and "captured" population, the effect can be more pronounced in terms of its level of impact. The "cure" may indeed include contributions from astrosociologists with sociological, anthropological, and/or psychological training working in concert with medical personnel to reduce its impact – ideally in the form of medical astrosociologists (educated in a field that currently does not yet exist).

"Medical sociology" is concerned with the relationship between social factors and health, and with the application of sociological theory and research techniques to questions related to health and the health care system.[5] Traditionally, medical sociology focuses on human medical issues on Earth (that is, medical issues unrelated to space). Three major areas of focus involve social inequality in health care delivery, ethical dilemmas and issues, and social epidemiology. These three areas will become important to medical astrosociology as well as it develops over the course of time.

In contrast, "medical astrosociology" focuses on the relationship between social-scientific factors and health as well, though it includes the rather critical addition of both social-scientific factors and biological factors peculiar to space. In practice, the issues carried over from terrestrial society will be additive to those unique to a particular

space environment. Put another way, *medical astrosociology* focuses on the practice and delivery of human medicine in space environments (i.e., medical issues in the context of societies and smaller social groups located in extraterrestrial locales). Medical astrosociology considers ethical and social problems associated with the delivery of medical care as well as access to the health care system of the space society. The example of dwindling or inadequate medical supplies demonstrates how both are affected. Such a circumstance can result in the inability or unwillingness to offer particular operations, drug therapies, or procedures to all citizens. Moreover, this situation could result in adaptive social patterns that favor "important" citizens over "regular" citizens. Even in smaller space settlements, social inequality can arise, producing some variation of differential medical care access/delivery for different social categories of citizens.

C. Proposal of the New Specialization Called *Medical Astrosociology*

This article serves as a preliminary discussion regarding the need to tie social-scientific principles normally addressed by medical sociology, anthropology, and psychology to medicine in non-terrestrial physical environments. Social-scientific issues related to space medicine are destined to comprise an important specialization under the purview of astrosociology and become of considerable interest to the field of space medicine. And while psychological issues have been addressed on a limited basis related to spaceflight operations, the larger context of these and other social-scientific issues, including newly recognized combinations of factors, in a larger societal context remains unexplored in a formal manner at the current time.

In *any* social environment, human beings cannot deliver medical care without the consideration of social, ethical, cultural, and personal criteria that inevitably complicate strictly biomedical decisions and require compromises in treatment based on a combination of these multiple types of criteria. Due to the fact that space is a harsh environment for human beings (as well as for their animals and plants), space medicine involves issues not normally as significant to terrestrial environments. Moreover, the same complex issues focused upon by the social sciences regarding terrestrial societies will become more complicated in isolated and enclosed space environments.

Some of the most important issues related to medical astrosociology receive treatment here in order to clearly demonstrate the need to develop this specialization. It ties together the two branches of science – the physical/natural sciences and the social/behavioral sciences – which normally remain separated in space research generally, indicating yet another reason for collaboration between the space and social science communities. It is best to carefully think through the details related to medical astrosociology now rather than play "catch up" following the need to do so on an emergency basis in future in some yet-unestablished space environment. As such, we must begin the dialog now about the interface between medicine and society in outer space, just as we do routinely on Earth. This proposal to establish and develop medical astrosociology represents a logical undertaking when using the patterns of our terrestrial medical systems as analogs.

II. Astrosociology in the Sickbay

Historically, the sickbay originated as both hospitals and dispensaries, or infirmaries, aboard seagoing ships. Casualties were expected on warships, of course, but these facilities are now common on both military ships and cruise luxury liners. In space, aboard crewed spacecraft and on cosmic bodies, this tradition will carry forward. For the purposes of this article, the term *sickbay* is largely a metaphor, -- a catchall concept – that pertains to any medical facility constructed in environments beyond the Earth's atmosphere. Thus, it can refer to medical facilities in space societies or aboard spacecraft. A sickbay represents a population's, or subpopulations, facility to treat the injured and sick members of the population.

The ability to meet the medical needs of the population will prove invaluable as mission times extend into months or years, or permanent habitats are built. It is not unexpected that the terminology may evolve into designations such as "hospital" and "clinic" in settlements with larger populations. Later in a settlement's development, the increasing number of sickbays will constitute a sophisticated social institution (i.e., the medical institution). Both the facilities and the health care system will inevitably move from the relatively simple to the complex; both in terms of medical capacity and social organization. This projection depends on a growing and thriving space society with adequate resources.

Thus, the health care system operating within a spacecraft or a settlement must become proportionally more sophisticated as the population size increases; otherwise, it may fail to meet the needs of the crewmembers/citizens. In large settlements, one sickbay cannot meet all citizens' needs, just as terrestrial societies require multiple hospitals and facilities in a single city. This requires much planning ahead of time in terms of the engineering and architecture – as well potential growth – of a physical habitat. First-aid stations in dangerous areas and spaced out to accommodate emergencies throughout the habitat will prove important. The average person will require at least

first-aid training to handle non-life-threatening emergencies. This type of health care system developed within terrestrial societies through trial-and-error among other processes. They are likely to be replicated in space environments as well, with additional social adaptations included based on unique habitat and space environment characteristics. In many ways, the explorers and settlers of outer space will subject themselves to physiological changes that also result in social-scientific consequences.

A. Scenarios Involving Medical Astrosociology

The social sciences will come into the sickbay out of necessity, in the form of medical astrosociology, just as they have in terrestrial medical facilities and research efforts. For one thing, citizens will not always have the luxury of "doing the right thing." In fact, provision of the best care for all patients in all circumstances by medical personnel is a luxury the population as a whole cannot always afford. In extreme situations, the very survival of the larger population may become threatened. Treatment of specific individuals may not benefit the population as a whole. It may become necessary, in essence, to sacrifice an individual for the good of the larger population. Various types of ethical dilemmas can crop up for a variety of reasons. A space physician may have to act on behalf of his/her own welfare that corresponds with that of the general population.

The following short examples, common in terrestrial societies, illustrate this point. Medical supplies and drugs are likely to be in short supply. What should one do if the dosage of a drug needed to fight one person's infection is projected to nearly exhaust the remaining inventory? Suppose the patient has a terminal condition. What if the use of pain medication would unreasonably drain existing resources to the detriment of other future patients? Is euthanasia a valid consideration based on the notion of ending suffering? If we send accomplished individuals to Mars to live in a permanent settlement, for example, they will reach old age relatively quickly. How will space societies handle gerontological issues in a small and isolated social environment? These examples should make clear the fact that reliance on purely medical theory is not the same thing as medical practice. Other issues, such as those related to social inequality and personal relationships, will receive attention later in this article.

Compromises and other ethical dilemmas will confront medical personnel. They will involve multiple criteria that require complex decisions before taking actions. Some of these issues will receive attention here as they provide the core substance of the new specialization called medical astrosociology. The combination of new environmental effects unique to outer space affecting health status and the common dilemmas associated with providing medical care will serve to demonstrate the dire need to develop medical astrosociology – and this unprecedented combination of variables will prove that this introduction cannot overstate the need to develop this specialization of ***astrosociology***. As a subfield of sociology, astrosociologists will bring the rich theoretical and empirical heritage of the discipline to space. This will represent a landmark change as sociology has, for the most part, focused its attention strictly on terrestrial matters. As a multidisciplinary field, astrosociology will achieve a similar achievement for the other social sciences. In the present case, social-scientific forces associated with traditional medical issues receive attention.

The great potential of astrosociology, however, rests in its potential to bring together scientists from various social sciences, behavioral sciences, and humanities in a way that encourages collaboration, with the overarching subject matter of outer space tying them together. Beyond this monumental precedent, members of the space community will almost certainly collaborate with astrosociologists as well; and many of them will probably come to call themselves "astrosociologists." For human space exploration to succeed, the *other* branch of science must take its place in the forefront of space theory and research alongside the traditional natural and physical sciences.[6] The present example of medical astrosociology serves as yet another important application of this principle, as physicians, patients, and others will recognize it is needed in the sickbay.

B. The Future of the Extraterrestrial Sickbay

Thus far during the space age, human efforts in the solar system have taken place very close to Earth. In low Earth orbit (LEO) aboard the ISS and even on the Moon, unless the spacefarers decide to isolate themselves, individuals and social organizations on Earth will affect them most strongly. This set of circumstances will apply to the earliest space ventures as well as the most proximate. Early missions are likely to be characterized by a much higher dependence on Earth than subsequent missions.

Terrestrial analogs demonstrate the need for citizens in a space society to acquire multiple skill sets. One good example of this could involve a medical doctor with psychiatric or psychological training, for example. Any society located in space, isolated from Earth and limited in size, will produce both social and psychological problems among the citizenry requiring the monitoring of the population and the provision of treatment when necessary. These social realities demand attention lest they become debilitating to individuals and larger social structures. Planners of long-term missions of any type must take these potential problems seriously to help ensure a successful outcome.

In space environments, whether on relatively short-duration or long-duration spaceflights beyond Earth orbit or within space societies, the sickbay will need to be much more capable than aboard World War II vessels, for example, and probably more capable than aboard contemporary aircraft carriers due to their isolated environment and the difficulties involved with obtaining supplies from Earth. Can *in-situ* resources be utilized to produce some of the medical supplies? Would this include "medical" compounds? This ability would probably prove invaluable as it would decrease the need to transport important medical equipment and supplies (including pharmaceuticals) from Earth to the settlement. The local "sickbay" could depend on Earth much more heavily than the more distant variations – the farther from Earth, the more autonomous they must become.

In the following decades, human beings will begin to explore, live, recreate, and work on space bodies – starting with the Moon and then on to Mars once the exclusive dedication to the ISS passes. As the closest cosmic body, the Moon can serve as a valuable platform for testing many important ideas and solving problems. One valuable approach could be to run daily operations as if the lunar was totally isolated whenever possible, and work through problematic issues without the help of mission control to the extent achievable.[7] Techniques and behaviors could be developed that will prove extremely useful in more distant and inaccessible locations from a terrestrial perspective, including on Mars. If a medical problem or any other type that threatens the mission arises, the astronauts could abort and return to Earth on an emergency basis. Otherwise, mission control would act largely passively in a monitoring mode. In practice, this change from the tight schedule imposed on astronauts may prove difficult to overcome. This new protocol deserves consideration even if implemented for a partial period over the course of a mission's stay on the lunar surface.

The relatively local sickbay that depends highly on terrestrial assistance will disappear as human social groups move farther away from Earth. *Ethnocentrism*, or the belief in the inherent superiority of one's own culture over others, will place pressure on a settlement to run its own affairs rather than take orders from a mission control entity on Earth. A substantial distance from Earth will place a strong amount of pressure on spacefarers to develop this likely pattern. For these reasons and others, the relatively local sickbay will not resemble distant medical facilities as the latter cannot depend on Earth assistance. That is, later missions will demand their autonomy to a much greater extent as they become more isolated and establish their own unique identity.

The practice of medicine in distant facilities will require autonomy. Communication with Earth will become inconveniently slow as the distance increases. The medical facilities of any space society will be able to receive a declining level of assistance from Earth-based facilities as the distance between the settlement and Earth increases. For example, telemedicine becomes too slow to be practical due to the long communication speeds involved. Surgeons will need to be part of crews and larger populations to cope with medical emergencies. Consequently, the sickbay must be capable of operating as a stand-alone facility. The specific illnesses and injuries that arise can receive treatment from medical personnel.

However, the character of the treatment regime will become tied to the settlement's larger culture – not to mention the subcultures that develop with many contrarian values and norms. In some cases, the fear of the affliction can be more devastating than the disease. Even the bravest among us possess limits. Ongoing isolation can amplify a person's feeling of loneliness and other psychological problems. Social life may suffer under excessive stress caused by demands of the leadership or when survival becomes threatened.

III. Outer Space: Unhealthy for People *and* Spacecraft

Despite their importance, social-scientific factors cannot account for the onset of all illnesses or other problems for individuals, groups, or the general population that develop in a space society. Outer space and other non-terrestrial environments present dangerous conditions for the human body. Biomedical causes for disease must receive their due scrutiny. In fact, then, both biomedical and social-scientific factors coexist, and neither should be favored in isolation from the other. For instance, it is quite possible that while an illness is caused by a particular pathogen, the pattern of its contraction, or the disease vector, may have social significance that can isolate its point of origin. In many cases, experts can implement a nonmedical solution.

Discussions in this section touch on various problems that are known to exist based on experiences within contemporary space programs. These biomedical problems should receive consideration along with the interrelated social and cultural issues that exist. It is almost certain that non-biomedical issues will differ in many ways in distant, isolated space environments from those we have experienced thus far; a probability that bears remembering as more extreme conditions will present additional challenges that require both new solutions and new compromises.

Officials within the societies on planet Earth will need to make countless decisions that relate to things like how many resources to allocate for solving the problems discussed below and how much risk is acceptable. Thus, an astrosociological dimension exists alongside the biomedical decisions that strictly focus on solving the problems

themselves. The unrealistic belief that medical doctors and epidemiologists can handle all of the issues related to illnesses and health care requirements without interference from other elements of society, developed from the perception that the natural branch of science is superior to the social branch of science, must end. Strictly biomedical approaches cannot cope with all of the problematic outcomes that present themselves, including their resolution. Such biomedical utopias do not exist on Earth and they will not exist beyond it, either. Therefore, medical astrosociologists will need to work with medical doctors and researchers in order to maximize the effectiveness in identifying and attending to all biomedical and medical astrosociological (i.e., social-scientific) challenges that develop. The fact that human beings and their social structures are involved must remain in the back of the minds of biomedical personnel.

It is not much of a logical leap to point out that if space is unhealthy for spaceships and space stations, it is also unhealthy for the habitats that enclose space societies. In fact, transfers from the spaceship to the permanent habitat seem almost inevitable. And, in fact, many scenarios for colonization call for a landing craft attached to the cruise spacecraft, the latter of which remains in orbit while its counterpart lands. Again, the biomedical issues that arise will inevitably result in astrosociological issues that require resolution in the form of a *biosocial* decision-making process. That is, biological problems will always occur in a social context. The only time this reality proves false is when just one person remains alive in a habitat; and no one prefers this outcome…

These biomedical issues receive scant attention here as their coverage by space medicine experts and others is widely available – this article concentrates of medical astrosociology for the most part. The purpose here is two-fold: (1) to point out that these dangers do indeed exist and (2) to emphasize that these dangers occur in a social and psychological context that requires attention. The latter issues will receive additional coverage in most of the discussions that follow. For the social scientist, it is important to keep in mind that biomedical issues underlie causes of disease. For the space physician, it is important to keep in mind that social patterns can account for patterns in the transmission of disease; cultural definitions can affect people's perceptions of health and illness, and thus their perceptions of risk; and health care delivery is subject to social forces that can lead to inequality.

A. Varying Gravity Fields

The evolution of the human species thus far in our history was always based on a specific level of gravitational force known as "1g." Each of the systems of the human body developed in response to this force. Thus, any gravity field that deviates from this level results in changes in the human body, whether the field is greater than 1g – or as more common in human experiences during a space mission – less than 1g. These changes include serious consequences to the human body, both transitory and potentially chronic.

1. Microgravity

A limited number of human beings have experienced microgravity – not technically weightlessness – in their efforts to explore the LEO environment. Humans have shown aboard the ISS that they can cope with microgravity through exercise over short periods of time. However, long-term exposure to such conditions almost invariably results in harmful physiological effects ranging from minor side effects to serious medical conditions. The list of physiological changes to the functioning of the human body in microgravity environments has been documented by NASA and other researchers to a great extent. These changes include: (1) dehydration; (2) cardiovascular effects that involve lessened blood flow due to decreased demand on heart; (3) bone loss and demineralization (loss of calcium and other minerals) – or the deterioration of skeletal system; (4) alteration of pulmonary function; (5) muscle loss / deconditioned muscles; (6) a decrease in production in red blood cells – resulting in mild "space" anemia; (7) loss of blood plasma and other body fluids, (7) balance disorders; (8) a weakened immune system; (9) "space adaptation syndrome" (SAS) characterized by nausea, headache, vertigo, lethargy, and sweating – affecting half of all astronauts, though only lasting a few days; (10) unknown effects on brain function due to increased blood accumulation; and (11) minor annoyances that include puffiness in the face, increased flatulence, weight and muscle mass during a long space mission, loss, nasal congestion and sleep disturbance.[†]

These effects and additional ones that impact on the brain conspire to reduce performance levels. On short missions with closely scripted instructions throughout the work regimen, these problems seem less detrimental to the individuals or to the mission. Longer exposure results in greater physiological problems and decreased performance. Long-duration missions beyond LEO may require artificial gravity as it may prove to be the only countermeasure available. Members of space societies on planetary bodies will probably experience fewer problems as they will need to adjust to partial gravity fields rather than microgravity.

[†] The effects of microgravity listed here were collected from documents and web pages that are part of NASA's main website (URL: http://www.nasa.gov) by searching for a combination of terms that included "microgravity."

2. Zero Gravity

A brief discussion of zero gravity (zero-g) deserves reflection. An environment approaching true weightlessness will befall humans traveling between planets in our solar system and those who eventually travel from our Sun to another star. Although the two concepts are often used interchangeably, zero gravity is different than microgravity. In zero gravity, there is very little force acting on the human body. The very small effects experienced in Earth orbit do not exist. Unlike microgravity, spacefarers are not in freefall around the Earth. Instead, they will find themselves even more susceptible to changes in their bodies due to the almost complete absence of gravity. While these changes will prove more pronounced than experienced in microgravity, the lessons learned in the latter environment will make adaptations to zero gravity easier to accomplish. The possibility exists also that exposure to zero-g over a considerable time period will produce new effects currently unknown to researchers.

Humanity's first "long-term" experience in zero gravity will occur when the first Mars mission get underway. Long-term spaceflights in open space will become a new experience for human beings (unless the spacecraft produces an artificial gravity field). Planners should prepare themselves for differences in the physiological effects as well as those in terms of behavioral effects that occur. Medical astrosociology will prove useful to help with the latter problems and contribute to a better understanding of interactive effects between the two. Perhaps one positive aspect of adjusting to Mars is that astronauts will only have to adapt to a 1/3g gravity field rather than the 1g field if they returned to Earth. The flight home all the way from will provide a more difficult adjustment period due to human exposure to zero-g.

3. The Moon and Mars

Spacefarers and settlers will experience long-term exposure to reduced gravity fields greater than microgravity during the course of the twenty-first century. Even with the Apollo landings on the Moon in the 1960s and 1970s, we know very little about the effects of 1/6g on the human body. In theory, it seems as though 1/6g is better than microgravity and the 1/3g gravity field on Mars is better than both 1/6g and microgravity, but very little data exists concerning anything except microgravity and 1g. We can only move beyond logical suppositions when humans actually live, work, and recreate in these space environments.

Long-term exposures to the gravity fields of the Moon and Mars will, of course, dictate close biomedical scrutiny of those involved. This approach represents the standard during the space age up until this point. Some attention to psychological issues has also occurred. However, we should take a much broader view. For example, we should monitor crewmember's social interactions utilizing sociological and social psychological insights to help them cope with problems within the *social environment*. This astrosociological approach goes beyond traditional human factors analysis, as will become clear in a later section. Medical astrosociologists would look for interactive effects between biology and social science induced by stress and other impacts of a reduced gravity field (among other causes of behavioral problems).

4. Solutions to Problems Induced by Lower Gravity Fields

Ensuring a peak health level among space travelers prior to their space mission will help to limit the effects of altered gravity environments. However, this will prove less practical the more civilians join crews. Private missions may not make such criteria a high priority; especially when corporations begin to construct space societies in orbit and on extraterrestrial planetary bodies. In any case, the level of training needed to produce professional astronauts will prove too costly to apply to the composition of large groups of people to travel into space. This traditional level of training will be provided for the flight crew a select number of other, probably including physicians. When developments occur that favor less well-trained passengers, other solutions to cope with the effects of lower gravity will increase in importance.

Vigorous exercise can do much to counter many of the problems listed above, although it cannot replace the 1g gravity field. On the other hand, it creates a problem. It takes up a lot of time. Aboard the ISS, for example, astronauts cannot focus on science while exercising. This situation degrades the mission and increases the cost of conducting science. Nevertheless, exercise will undoubtedly become incorporated into the schedules of spacefarers in all scenarios, whether short-term explorers or long-term travelers and settlers.

Drug therapies and other forms may be capable of altering some of the effects in human physiology that present dangers to human health. For example, the decreased immune system may be stimulated to function more normally compared to terrestrial standards. We will need to overcome the decreased potency of drugs as part of the therapies provided in order to meet desired levels of effectiveness. While this approach seems promising, there is no guarantee that it will provide a robust countermeasure.

Artificial gravity field at, or near, the 1g threshold provides one solution for spacecraft and space stations. While it seems like an obvious solution to counter all of the ills produced in space, it is nevertheless expensive to implement. Even so, NASA has taken this adaptation to spaceflight under consideration for its first mission to Mars. (On planetary bodies, however, this approach cannot work, so crews/settling populations will need to adapt to the

gravitational conditions they encounter). Even if a mission implements this strategy, those aboard a spacecraft must prepare themselves should equipment or software failures present themselves. They will become exposed to all the problems associated with micro- or zero gravity discussed until they can repair the gravity system to full functioning order once again.

In summary, no single solution to address all physiological/biomedical problems that develop currently exists. It may never exist. The overall solution will probably resemble a complex patchwork of part. A comprehensive approach combining several medical, physiological, and technical components will prove necessary to counter the multiple problems associated with spaceflight and settlement.[8] Until countermeasures can be developed, human beings living in space environments will become subject to elevated health risks that extend throughout their life cycles, even if they return to Earth. The biomedical component is definitely a genuine concern that requires ongoing research and monitoring of humans in various space environments. Moreover, the overall solution to reduced gravity fields involves even greater complications that significantly transcend the physiological and biomedical dimensions.

Social and psychological ramifications also exist. Thus, comprehensive solutions must involve a combination of biomedical and *medical astrosociological* solutions will prove necessary. The most dangerous practice – based on the traditional approach by the space community – will be to apply the former while largely neglecting the latter. The physiological changes and resulting hardships will result in psychological problems as well as those reflected in social interactions among the crews/settlers. We need to prepare ourselves for both contingencies. Humans recover generally well following typical short-term missions. Long-duration space missions will provide much more difficult challenges for spacefarers and settlers – and these challenges can result in compounded psychological conditions, social conflict, and other problems pertinent to astrosociology rather than strictly medicine or biology. Undoubtedly, solutions under these conditions will transcend those aimed solely at addressing biological issues. Medical astrosociologists could provide forms of relief and at least mitigation for the physiological effects that manifest themselves as behavioral problems for the individual and during the course of social interaction with other crewmembers/space society citizens.

B. Radiation Everywhere

Without a strong magnetic field and atmosphere such as those provided by Earth, space travelers and settlers will find that they cannot escape high levels of radiation in other space environments in our solar system. On the Moon, for example, the lack of atmosphere exposes the entire lunar surface to radiation without mitigation. On Mars, with a thin atmosphere only about one percent of the Earth, the radiation level is so intense that it may force human settlers to build habitats underground as well as strongly shielded vehicles for excursions on the surface. Some investigators regard the high level of radiation as a "no starter" for settling Mars while others argue that it is quite possible to counter the effects of radiation.

1. Cosmic Radiation and Its Consequences

Definitions associated with the catch-all concept of "cosmic radiation" need not become too technical for the purposes of this article since the main emphasis relates to medical astrosociological issues. Suffice it to state that cosmic radiation presents a myriad of dangers to spacefarers and settlers. With that stated, then, a general definition is in order. The term "cosmic radiation" may refer to (1) the cosmic microwave background radiation that permeates space (considered low-level exposure and, more importantly in the present context, it refers to (2) the higher energy particles that all luminous objects in the universe create on a constant basis. The Centers for Disease Control and Prevention (the CDC) defines cosmic radiation as "radiation produced in outer space when heavy particles from other galaxies (nuclei of all known natural elements) bombard the earth," a definition that still emphasizes a terrestrial perspective.[9] However, it is easy to take the logical leap that these particles will bombard a spacecraft inhabited by human beings as well.

Photons of all different energies/wavelengths are being created by our sun, other stars, quasi-stellar objects, black-hole accretion disks, gamma-ray bursts, and supernova explosions – consisting, then, of a large number of known and unknown sources. These objects also produce high-energy massive particles such as electrons, muons, protons, gamma rays and anti-protons that travel at, or near, the speed of light. In open space, these energetic particles pose extreme danger to human physiology. On cosmic bodies, they present lower yet significant risks depending on the characteristics of a particular space environment. On the Moon and Mars, greater levels will bombard settlements than humans are accustomed to on. Human health will suffer as a consequence. In space, of course, this same cosmic radiation will strike spacecraft and potentially their occupants, dependant on the amount of shielding present.

Acute exposure involves a large amount of radiation over a short period of time. In contrast, chronic exposure involves a low dosage over the course of one's life, or at least over a long period. High levels of exposure results in

radiation sickness, or *acute radiation syndrome* which occurs only when all four of the following contingencies are present together:

> [t]he radiation dose was high (doses from medical procedures such as chest X-rays are too low to cause ARS; however, doses from radiation therapy to treat cancer may be high enough to cause some ARS symptoms), (2) [t]he radiation was penetrating (that is, able to reach internal organs), (3) [t]he person's entire body, or most of it, received the dose, **and** (4) [t]he radiation was received in a short time, usually within minutes.[10]

While humans on Earth are protected from most of the harmful radiation that makes it to our home planet, those in space are exposed to greatly elevated doses, then. In space, these high energy particles can prove extremely harmful. The "vacuum" of space is characterized by high levels of cosmic radiation.

Within our solar system, for example, solar flares, produced by our Sun, can irradiate humans with high doses of nearly all forms of electromagnetic radiation in addition to other energetic particles. Solar flares can strike spacefarers with lethal doses of radiation as well as lower levels of exposure, depending on their severity and direction. Strong solar flares cause immediate harm to unprotected human explorers. These largely unpredictable eruptions will force spacefarers and settlers to construct both contingency plans and countermeasures. Both spacecraft and space society habitats will require protective systems. For settlements on cosmic bodies, taking advantage of protective elements such as caves and regolith can greatly protect humans, animals, and plants.

The likelihood of the development of cancer and other illnesses will elevate without precautions. Death can occur rather quickly in the most serious circumstances. Countermeasures are not optional though the amount of protection will vary from mission to mission. Such decisions represent social calculations that take into account compromises that include various cost options and risk tolerance level. It will be important that social conditions and behavioral patterns support protocols to mitigate the effects of radiation (and all other threats of human life and health in space environments).

2. Countermeasures and Ethical Considerations

The ubiquity of radiation in space requires a compromised solution that involves a calculation between the most effective type of protection from radiation as the extreme yardstick measure on the one hand pitted against the level of payment considered appropriate for the resources needed to construct shielding in terms of money, time, and limited physical resources on the other hand. The latter refers to the level of protection selected. How much protection is morally acceptable? How much is affordable? Thus, the very consideration of countermeasures creates the necessity to develop social policies that reflect a crew's or citizenry's reasoned position against the risks associated with cosmic radiation. Shielding is mandatory to the extent affordable. Only when unlimited *in situ* resources exist to meet criteria of the extreme yardstick can planners forego this compromise. Still, on the Moon and Mars, excursions outside of habitats and vehicles will make the shielding provided by spacesuits the only protection available. Thus, compromises seem inevitable.

Part of the shielding strategy will almost certainly involve drugs and various types of therapies. It will probably prove impossible to provide radiation shielding in all circumstances. The manufacture of drugs in space societies far from Earth, for example, will become necessary as the resupply from the home planet will become impractical based on current propulsion technologies. Drugs and therapies will need to be developed to protect against the effects of radiation at low to moderate levels (a preventive strategy), but there may be other costs to health and lifestyle. Drugs and therapies needed to counter such high levels of radiation will inevitably produce side-effects. Reactionary treatments, such as chemotherapy or other medical protocols, may become necessary due to long-term exposure to high energy particles at high, medium, and even low levels.

The difference between a correct or incorrect decision in any of these areas (or others) can result in either a healthy settlement population or an uncontrollable outbreak of cancer and other illnesses. In a worse-case scenario, bad social policy decisions can result in both medical *and* psychological consequences. Such added complexities to the social lives of space crewmembers or space society citizens can produce a standard of living that becomes unbearable. High levels of a variety of *social problems* – including drug use and deviance, including crime – may well result. With this in mind, planners of long-duration missions and space settlements (societies) must balance issues related to space engineering and architecture with those relevant to medical astrosociology. The best solutions for engineering are not necessarily the best solutions for people.

C. Dusty Complications

If the regolith on the Moon is any indication, astronauts and other spacefarers will find themselves coping with the contamination of their equipment and potentially health issues within their habitat. The benign soil human beings take for granted on Earth will not characterize their new locales beyond Earth. Lunar regolith can be as sharp as glass shards. Long-term habitation will require various strategies to cope with contamination and damage to lunar posts, vehicles, spacesuits, and other equipment. While spacefarers will kick up dust, one saving grace relates to the

fact that the lunar environment lacks an atmosphere and therefore does not experience wind storms blowing dust everywhere. Even so, lunar dust will present long-term residents with an ongoing challenge.

Mars presents similar risks. However, Mars presents explorers/settlers with a serious additional problem. Dust storms can cover the entire planet for months. They obscure visibility so that work is much more difficult and dangerous. Static charges during dust storms may cause equipment, including spacesuits, to become compromised, or even to fail. Minimizing risks through engineering solutions will become important. Additionally, behavioral precautions may also prove necessary in concert with other efforts to protect equipment. From within the habitat, the inability to view the Martian landscape may well result in a form of melancholy similar to that experienced by those who must endure severe snowstorms on Earth. Time spent not working would need to become occupied with other activities that focus people's attention on positive distractions.

The preventative measures needed to cope with dust will force alterations in the lifestyles of spacefarers. When returning from a long and grueling sojourn outside of the habitat, one or more individuals may not feel up to following the protocols precisely. Shortcuts may result in an unhealthy level of dust finding its way into the living quarters of the entire crew. How will others' affected by this type of transgression interact with those responsible? Social relationships may be altered by such a situation. The result becomes a combination of biomedical and social psychological problems that require a more complicated set of solutions than merely ridding the habitat of the dust.

D. Is It Night or Day?

The *Circadian rhythm* is defined as the master clock that regulates a host of biological functions. They regulate human behavior in unison with their environment. On Earth, the twenty-four hour cycle and roughly equal timing of it's night and day components impacts on everyday behaviors such as feeding and sleeping patterns. Consistent circadian rhythms daily have proven important to everyday life.

Once space travelers leave Earth, they cannot rely on the twenty-four hour cycle that regulate their biology – not to mention all of the other cues unique to Earth that govern healthy biological functioning. Human beings evolved on Earth, of course. As such, the rhythms associated with our biological-clock have adapted to the terrestrial environment. The body's adjustment to new environmental conditions presented by space environments causes disruptive alterations as it attempts to find a new rhythm cycle.

Most human beings cannot perform as well when the twenty-four hour clock is disrupted. Accidents increase and attention to detail decreases, including the interpretation of reality such as reports and computer monitoring information. This can become disastrous in a space habitat environment controlled by computers that require constant monitoring by human operators. Ongoing or unpredictable effects akin to jet lag can significantly compromise work performance and potentially endanger a spaceflight mission at a critical moment, for example.

Various methods must be employed to counter negative effects such as lowered performance due to fatigue and boredom. The use of bright lights may well help, along with the reduction of the number of shift changes and the inclusion of regular recreational or exercise breaks. The most effective methods probably seek to mimic the same cycles found on Earth. A form of permanent light therapy could be employed by mimicking the 24-hour cycle – with 12 hours of light and 12 hours of darkness – within the habitat. Using this method, the outside cues of lightness and darkness would need to be hidden from sight. Views of the landscape on Mars, for example, would only be available when the outside conditions happen to match the light cycle within the habitat. The opening and closing of porthole windows could be controlled by a computer.

Adaptations to the conditions of various space environments will need to differ accordingly. To the extent that conditions more closely match terrestrial conditions, fewer adaptations – or less severe ones – will be necessary. In any case, changes in human behavior and social interaction will occur. Some will result from the effects of disruptions to the Circadian rhythm while other will involve strategic behavioral changes that seek to lessen the negative effects. Astronauts and civilians in space must learn to recognize the symptoms of getting out of synchrony with their Circadian rhythms.[11] The same type of skill must be developed for all biomedical and astrosociological (i.e., social scientific) problems that develop.

E. Earth Microbes and Space Microbes

Complicating well-known negative impacts on the human body, human beings and their machines regularly transfer terrestrial microbes into space with them. Medical astrosociologists and space medicine practitioners must not lose sight of the potential harm posed by Earth microbes as well as the behavioral patterns that increase the favorability of infection among space travelers/settlers. In addition, the interaction between Earth microbes and extraterrestrial conditions may in fact result in new medical problems never witnessed before in various ways (e.g., new forms of pathogens or a rapid rate of infection). This possibility may well develop, especially during long-term missions and permanent space settlement as the Earth microorganisms will have time to mutate and infect humans

systems. The assumption that terrestrial microorganisms were eliminated from previous space missions, and thereby from future missions, requires reconsideration.

The experiences with the Mir space station proved positively that humans bring microorganisms with them that contaminate their spacecraft even when it launches in pristine condition.[12] Humans bring microorganisms with them, making any pretense of a germ-free environment impossible to maintain when living in space within closed physical environments. While the risks to human beings seem more obvious, Earth microbes also consume and otherwise harm the interior elements of spacecraft and space society habitats.

1. Terrestrial Extremophiles in Clean Rooms

Hitherto, it has proven impossible to fully rid a NASA clean room of unwanted (and often undetectable) microorganisms. These extremophiles, defined as organisms that thrive under conditions too extreme for human survival,[13] represent an important threat to astronauts and other humans who go into space. It is quite clear that this problem requires greater attention.

When organisms survive in the clean room, the facility's name represents a misnomer. It is not clean. Many of the current cleaning methods used by NASA to clean Earthly contamination from its spacecraft have been shown to be ineffective.[14] A further implication looms as well. These survivors are likely to be transferred from the room to the spacecraft, space station, and/or settlement habitat. While it remains impossible to completely eliminate earthborn bacteria in clean rooms, to do so must remain the goal in order to ensure the greatest possible minimization of hitchhikers

In the context of this article, this means that some potentially harmful organisms are likely to come aboard spacecraft with human beings, even with the use of improved sterilization techniques advocated by Venkateswaran and his colleagues. For human missions, this can result in health and even mortality issues. If illness becomes a major problem, this will require behavioral changes among the members of the crew or settlement. Quarantine protocols may become necessary in extreme cases, placing additional stress on individuals and their social interactions. Awareness of these potential problems can develop into practices that minimize the likelihood that microorganism grow out of control or spread among humans and parts of the spacecraft.

2. An Unfavorable Human Health Environment

An unfortunate combination of conditions exists in space habitats if Earth pathogens survive in a spacecraft or make it into a habitat housing a space society. The combination of fast-growing bacteria that find the spacecraft environment favorable and humans experiencing weakened immune systems in reduced gravity fields make humans more susceptible to these hearty terrestrially-originated microbes. Extremophiles that make it to the spacecraft aboard human hosts and equipment may prove difficult to eradicate – even when they are recognized by the crewmembers. Different organisms will cause different problems consistent with their biology. Whatever their particular preferences, they pose risks to humans in space environments.

In a space settlement physical environment, these extremophiles – depending on the type of organism – may cause havoc. Such a scenario becomes more probable, and harmful, when the leaders and the rest of the inhabitants fail to recognize this situation or take it seriously enough. The residents of isolated, closed habitats can easily find themselves in the midst of an epidemic due to mutated Earth microorganisms if they are not careful enough.

3. Space Microbes

A brief discussion of extraterrestrial microorganisms deserves attention. The most likely extraterrestrial microorganisms to be encountered first will reside on the Martian surface and subsurface. After all, human explorers will seek them out. Thus, the possibility of potential contamination from space microbes must receive ongoing scrutiny. The examination of rocks, regolith, and other materials within the spacecraft or habitat must occur with the highest protocols in place. Martian microorganisms, if indeed alive, may even interact with terrestrial microorganisms to produce heightened threats.

For missions that return astronauts, spacecraft, and extraterrestrial materials to Earth present a danger to a great deal more human beings. Quarantine protocols will be required for astronauts, their equipment, and materials to reduce the likelihood of contamination. As the study of NASA clean rooms discussed earlier shows, however, the full elimination of a Martian extremophile – a characteristic surely required to survive on Mars – may prove impossible to guarantee.

F. Biomedical Problems in Space within an Astrosociological Context

The work involved with identifying, solving, and implementing solutions involves human beings cooperating in organizational structures. Only though this cooperation, made possible by supportive policies and decision making at higher levels, could crucial knowledge exist and become incorporated into solving crucial problems. In the area of space research involving the risks to human biology, the problems are many, some almost insurmountable, and the solutions potentially outrageous in terms of implementation and thus expense.

Solutions may not characterize all elements of space exploration and settlement. Many elements may result from compromises that are thought to minimize risks, but not expected to fully protect all spacefarers. The very decision to become a spacefarer in the early years of voyages that traverse beyond Earth orbit in fact involves a social contract that states the acceptance of the risks involved.

1. Isolated Physical Environment

In addition to the other problems discussed, a closed physical environment will result in the accumulation of toxic gases, chemicals, and other unhealthy elements in the spacecraft or habitat. The buildup of carbon dioxide itself can result in tragedy unless closely monitored. While the reliance on automatic systems lessens the load on the crew or citizens of a space society, a malfunction can undo any of the benefits they provided up to the point of potential disaster.

The elevated dangers associated with living in a close physical environment will produce stress at the individual level. Occupational duties of all members will need to include some medical and first-aid training in addition to the monitoring of the physical systems they encounter. The latter ability could potentially catch a malfunction of a system before it results in a cascade failure that threatens the entire spacecraft or space society habitat. The interaction between the physical environment and social environment represents a vital survival mechanism in this context as well as many others.

2. Isolated Society: Living in a Closed Environment

Social interaction arguably becomes even more important in an isolated social environment. Spacefarers will need to work together in cooperation to live social lives characterized by harmony. As with physical problems that develop, social conflict requires resolution in order to avoid potential disaster. In small crews or populations, the solutions are potentially more difficult to achieve due to the limited number of potential partners of interaction that exist within the habitat. In larger groups, a strategy to avoid a particular person may suffice. In small groups, every person is potentially vital to the success of the mission, making this strategy unworkable.

Moreover, psychological problems of a confined living space will result in problems related to social interaction that may escalate beyond the micro level. On a simplistic level, individuals who develop mental problems or even psychological disorders will often interact inappropriately with others, and this new social reality potentially results in social problems that transcend individuals. They can easily affect the entire group or larger in ways the harm individuals who were unrelated to the original conflict.

3. Coping with the Unhealthy Elements of Outer Space

Unhealthy elements exist in outer space. The methods employed to hope with them stem from social policy decisions. A series of cost/benefit analyses may be required if full protection against various harmful elements proves untenable. Full protection is highly unlikely. Original risks are assessed and countered by original planners of a given mission. Additional reactions to dangers are based on the ethical standards of the leadership of a space crew or space society.

The dangers presented by space exploration focus attention on the age-old question. Is space exploration worth the effort? That is, are the costs are worth the benefits? Space exploration requires expensive countermeasures and life-threatening actions to accomplish even in Earth orbit. Moving beyond Earth orbit results in an increase of the difficulties and dangers involved. Even so, a dedicated segment of humanity has answered this question in the affirmative. It seems that our species' movement into outer space represents a cultural imperative for reasons that relate to ensuring survival and other important matters.[15]

Thus, another question is probably more appropriate as humanity will almost certainly attempt to engage in space exploration. Can we overcome the biomedical *and* social-scientific challenges we will face in the various space environments we encounter? If space exploration is indeed a cultural imperative, humanity will attempt to identify and counteract the dangers involved. In fact, it has begun to do so already in fact as well as in theory.

The use of robotic systems to accomplish extravehicular and extra-habitat activities can lessen human exposure to some sources of harm such as radiation. In contrast, human beings must cope with the pitfalls of space exploration discussed in this section along with others still unidentified. Individuals and their space societies will be challenged to survive, and moreover, to thrive in hostile environments. The study of human behavior in these circumstances will require astrosociologists to live and work within these types of crews/populations – and this simple fact requires that we begin to educate medical astrosociologists in our mainstream colleges and universities, perhaps alongside students specializing in space medicine.

IV. Transformation into a New Species?

The accumulation of all the differences between a given natural space environment and the terrestrial environment will most likely result in permanent physiological changes in the first generation of *permanent* space

settlers who refuse to come back to Earth. The potential resort is unprecedented *transformation* within two generations rather than the comparatively slow pace of natural selection, or the terrestrial form of evolution of our species that we take for granted. Adaptation to sudden, long-term changes will most likely alter the first generation of space citizens. Subsequent generations are likely to become altered even more quickly and substantially. The combination of gravity fields that vary from 1g and increased radiation, as two obvious examples, could cause physiological changes and mutations, respectively, in humans. Some changes will result from natural conditions of space environments whiles others will result from purposeful actions taken by human beings themselves. In addition, some purposeful changes will attempt to counteract harmful cosmic conditions while other will seek to improve upon the design of the human being in a given space environment.

As Charles Darwin has stated regarding the process of evolution, "It is not the strongest of the species that survive, or the most intelligent, but the one most responsive to change."[16] Indeed, human adaptation to environmental conditions detrimental to human physiology and psychology will prove a deciding factor in the success of human settlements and long-duration space travel. Additionally, can human social groups construct social structures to regulate social life in such hostile conditions? That is, can a space society survive as a social system even if it solves the physical dangers of its space environment? Will the countermeasures required prove too costly in terms of their negative impact on social life? The social environment must function properly just as the physical environment must.

The current discussion does not intend to speculate about the extent or type of adaptations that occur. Rather, it assumes that significant changes will occur and raises relevant issues consistent with a medical astrosociological approach. In this way, the relevance of medical astrosociology becomes more evident. Space environments will require unique augmentations that become implemented as science and technology allow, as long as *social values* protected by *social norms* allow them.

A. Pregnancy, Fetal Development, and Birth in Extraterrestrial Environments

While not emphasized here due to the purposes of this current discussion, issues related to human sexuality in space environments will undoubtedly comprise an important area of study. Issues such as crew composition (ratio of males and females), sexual relations in varying gravitational conditions, the social and psychological impacts of coupling and breaking up on social groups, and various gender issues related to power and inequality will require investigation. The current discussion focuses on pregnancy and fetal development as it relates to the potential transformation of our species.

Pregnancy in space is a new frontier in itself. New complications will inevitably occur. The first pregnancy in a particular environment will represent an experimental condition with all of the associated risks that comes with any unknown phenomenon. The ethical implications of this situation are serious as no one knows how increased radiation, a lower gravity field, and other unique factors of a particular space environment will affect the development of a fetus. Such a pregnancy would need to be monitored with unprecedented attention.

1. Medical Astrosociological Issues

Unique complications during pregnancy may result in a conservative reaction in which the pregnancy is terminated. On the other hand, greater risks may be tolerated due to the need to increase the size of the population. How physicians, potential parents, and the community at large react to various types of biomedical complications represent the types of issues medical astrosociology will develop to study. What types of variations from the terrestrial model would warrant an abortion? What types of risks will be viewed as acceptable and allow for a full-term birth? The types of issues raised below clearly demonstrate the strong connections between biomedical and social-scientific phenomena related to space exploration and settlement.

Important issues arise within the space society. If an infant is born "healthy," how will it differ from "normal" infants? Assuming that a successful birth occurs, how will space citizens representing the original settlers handle these differences? What forms and levels of inequality might develop? What will its characteristics look like? What issues related to social inequality will arise over time in various social situations? Will altered humans lack "human" rights or will they develop the special rights of elites? How will the members of the new generation(s) react to inequality? Thus, social inequality based on a social bias akin to race and ethnicity may develop. Conversely, the first generation may accept any outwardly physiological differences that develop without substantial levels of prejudice or discrimination due to the need to add to the population base.

In turn, how will terrestrial human beings handle any differences that arise among the offspring of space explorers or settlers? If the citizens of a space society or long-term expedition become differentiated from their human counterparts on Earth, then their social relationship will become altered as well. Can a person born on Mars or the Moon ever live "normally" on Earth? Can he or she even survive in the Earth's 1g gravity field – that is, can such a person live on Earth if deciding to leave the space environment? Physical differences will probably hasten the

degree of *ethnocentrism* that develops, which is defined in this context as a set of attitudes employed to judge other societies by the standards that apply in one's own society. If physical differences develop vis-à-vis the bulk of the human species living on Earth, then unequal relations will develop as they always have in the past. History has shown that colonies are normally controlled from afar. Will the nations or corporation paying for the establishment of a particular settlement send undercover agents to ensure their investments are protected? Will they attempt to govern them overtly?

The implications of this scenario are not trivial. Due to the transformation process and the high level of isolation that exists in distant space societies, it is certainly possible that an extreme form of ethnocentrism will develop. An extreme level of distrust of human beings on Earth could potentially result in a separation of the space society into a distinct nation-state apart from any other nation on Earth. It may take time to develop for social-scientific reasons, but it would result in a new form of international relations, termed here as *interplanetary relations* (to be discussed shortly at the end of this section).

B. Enhanced Humans in Space and on Earth

It is clear that even humans living on the Earth will seek to better themselves physically as well as culturally. In space, enhancements may prove the difference between life and death for a population bombarded by cosmic rays and other harmful environmental conditions. The changes to human anatomy and functioning emphasized here go beyond evolutionary adaptations. Instead, they involve purposeful manipulations of the human body.

1. Cybernetics

The evolution of human beings will almost certainly involve a mechanical/computerized component. The creation of *cyborgs* – that is, part biological, part mechanical/electrical human beings – will appear on the Earth to improve health, longevity, and capabilities. For space exploration, alterations in the human body and its systems will occur to increase the survivability of human beings in various space environments. Zey[17] refers to this process as *cybergenesis* and considers it already underway on Earth.

One type of cybernetic improvement involves augmentation of the human heart. For example, if the heart atrophies in a reduced gravity fields, it would prove beneficial and wise to either improve its function, and keep it from atrophying, or to replace the biological original model altogether with a biomechanical version. If a particular individual wanted to live on Earth once again but his or her heart was too weakened, the same alternatives may make this possible.

Another example regards the augmentation of the human brain so that multiple crewmembers or settlers can be "outfitted" with multiple types of knowledge and skill sets. For small populations in space, this is often cited as an important capability. As with other parts of the body, it may prove necessary to shield the brain from radiation. Other examples include augmentation of limbs, strengthening of torso, and so on, for humans who live on a planet with a gravity field that exceeds 1g. At the other extreme, those living most often in weightlessness may require augmentations that simulate a 1-g use of their limbs through the provision of some sort of built-in resistance.

Whether or not these cybernetic enhancements become common, their consideration is already underway. Improvements on Earth of hearing devices, artificial limbs, mechanical hearts, and other advancements make it likely that many of them will have applications for space exploration. Are all of them ethical? If some are not, what standards will be applied to make such decisions? The ability to do something is not equivalent to the movement forward to do that thing. Societies, social groups, and subcultures decide the proper use of material culture. Nothing is automatically acceptable and may, in fact, quickly become defined as deviant.

2. Genetic Manipulation

Humans in the most extreme space environments may need to manipulate the human genome in order to respond to two major categories of issues: (1) the need to repair and/or improve human physiology in order to counter harmful cosmic effects and (2) the desire to implement biological enhancements to the human body for other reasons. The former issues tend to focus on survival of the social group. For example, cosmic radiation may cause harmful mutations or cancerous growths. A higher resistance would result in a greater tolerance of previous harmful or even deadly forms of radiation. The same would apply to a greater tolerance of Martian dust. The latter issues focus on improvements that make living and working in a particular space environment more productive, healthier, and even more comfortable. An example could be a genetic enhancement that created a higher tolerance of the extraordinary Martian cold climate.

3. Human Enhancements and Social Change

There is little doubt that enhancements to the human being as currently structured, whether through cybernetics or biogenetics (and probably through a combination of the two), will result in social change. Indeed, their implementations will occur in a social context and thus unavoidably result in social consequences. Most often, these consequences will produce both positive and negative effects. On a positive note, human capacities of various sorts

will receive enhancement. In its earlier years, when enhanced humans live with unenhanced humans, a new form of social inequality may well emerge! What if enhanced humans gain power in the space society? What if enhancements are unaffordable to all citizens due to a high price or unavailability of resources? Based on human history on Earth, a scenario in which one subculture attempts to control others would probably emerge.

Societies will need to make informed decisions about what types of enhancements become regarded as acceptable versus those that are not acceptable. If deemed too harmful to society, they may result in one or more legal norms (i.e., laws) that prohibit them. Any type of enhancements to human biology or physiology will require control through social policy decisions that conform to the social values and norms of a particular society, whether on Earth or beyond its atmosphere. All of the issues regarding cybernetics and biogenetics possess strong social and cultural components that place them firmly in the purview of medical astrosociology. Space societies will decide which types of enhancements are acceptable and how to cope with biological problems created by their space environment. A variety of influences will shape their decisions, so different societies will formulate their own unique decisions. These unique decisions will result in societies with different priorities, characteristics, policies, and actions.

As in the other areas of theory and research involving space medicine, collaboration with medical astrosociologists will improve the likelihood that a society, and not just individuals, can survive in a hostile and isolated space environment. More generally, the study of such a society on its own terms utilizing the scientific method will result in the best understanding of how it operates as a self-sufficient social system and, furthermore, how the accumulation of social changes affect how it will interact with entities on Earth. The histories of different space societies will result in multiple possibilities for space societies' relationships with Earth as a whole, and differences will develop between any particular space society and each of the nation-states on Earth.

C. Interplanetary Relations

If, in fact, one or more "new" species develop due to the effects of an altered gravity field and/or other conditions that affect those who live in space permanently, it seems likely that these individuals would come to view humanity as a different species than themselves, and vice versa, so that each potentially views the other as consisting of "space aliens." Mistrust on each side could quickly develop. In fact, ethnocentricity would likely cause this schism even if the members of the space society did not become altered physiologically. The separation itself, the isolation, would pressure the leadership of the space society to protect its citizens over the interests of those who live on Earth. The biological differentiation would only serve to increase the severity of this process in terms of their perceived separation from humanity.

Thus, even without physiological changes, ethnocentricity will hasten to develop due to the high level of isolation experienced by the population in addition to the need to fulfill its unique needs. It will increase the level of group cohesion among the group members in the settlement that will result in in-group/out-group distinctions. Unique problems faced by settlers compared to their terrestrial counterparts, whether medical or otherwise, will inevitably result in a relationship between the two rather than self-imposed isolation. A unique culture will develop in a space society that reflects a population's unique experiences off their home world, though its foundation will consist of terrestrial norms and values. Ethnocentrism alone could account for many of the differences that develop. They would develop even without the onset of physical differences, whether biological or cybernetic enhancements. Physiological changes would only serve to exacerbate the situation.

In any such scenario, the development of *interplanetary relations*, akin to foreign relations of Earth, would develop due to the isolation of the settlement, establishment of a societal social structure, and the likelihood of some permanent changes occurring to human physiology. A new type of relationship will form between the space society and its terrestrial counterparts. This new relationship will seem familiar in many ways as it will be characterized by cooperation, conflict, distrust, and tension – the same traits found between nation-states on the Earth. Differences will also emerge that we cannot predict due to the fact that interplanetary relations between *societies* still represents only a theoretical possibility.

V. Social Epidemiology in Terrestrial and Extraterrestrial Environments

The acceptance of social epidemiology is not universal, as will be discussed. However, the argument presented here adheres to the position that social epidemiology is a vital approach in an isolated and technology-dependent space society or spacecraft on a long-duration mission. And while these scenarios will not manifest themselves in the near-term future, their eventual success will depend on the utilization of a comprehensive epidemiological knowledge base when a crisis occurs or threatens to arise. Reliance strictly on biomedical data, while they are indeed important, amounts to merely a single dimensional approach utilized to understand a multidimensional

problem. *Social* epidemiology, though limited in social-scientific terms, takes into account both biomedical and a limited number of social-scientific (i.e., astrosociological) variables, and thereby allows for the possibility of collaboration among members of the space science community and the medical astrosociology community. In contrast, astrosociology allows for the same possibility on a larger scale due to its multidisciplinary and multi-topical nature. The latter refers to the many specializations of astrosociology such as medical astrosociology, applied astrosociology, planetary defense, and space societies.

A. Biomedical Epidemiology

Epidemiology – in its "purest form" with a focus only on biomedical variables and issues – is usually defined as something like the study of (1) the incidence and prevalence of disease in populations and (2) with the detection of the source and cause of epidemics of infectious disease.[18,19] Thus, many physicians and other medical researchers favor a separation between medicine and sociology and the other social sciences. Or, to put it another way, they favor a separation between biomedical factors and social/cultural factors. In its so-called "purest form," then, epidemiology focuses on biomedical factors to the exclusion of social factors. The latter are evaluated as unimportant or secondary to core epidemiological issues. For critics, the question arises as to whether medical practice, contraction of illness, and health care delivery can be understood in isolation rather than within a social context. Many advocates of a purely biomedical approach uphold the traditional myth held by many trained in the natural sciences that the social and behavioral sciences are inferior – and not really "sciences" – so they have hold relevance to the "scientific" issues under investigation. For these epidemiologists, disease is caused and distributed due to entirely biological factors, despite the fact that their occurrences are firmly rooted in society.

B. Social Epidemiology, or Epidemiology in a Social Context

The basic definition of *social epidemiology* is a branch of epidemiology that studies the social distribution and determinants of health and disease in populations.[20] Different societies are recognized to produce their own unique patterns of illness and health care. Thus, each society requires separate scrutiny.

Cwikel expands on Honjo's definition above to provide a more comprehensive definition below that transcends the biomedical emphasis of the field of epidemiology.

> Social epidemiology is the systematic and comprehensive study of health, well-being, social conditions or problems, and diseases and their determinants, using epidemiology and social science methods to develop interventions, programs, policies, and institutions that may reduce the extent, adverse impact, or incidence of a health or social problem and promote health…Social epidemiology is the combination of epidemiology (the study of the distribution and determinants of disease and injury in human populations) with the social and behavioral sciences.[21]

The emphasis on social problems allows for an activist approach to seeking and implementing solutions, according to Cwikel. The study of social problems, both medical and other forms, and attempts to solve them (an activist approach that is part of the practice of applied and public sociology) represent a long-standing tradition within the sociological discipline.

While the members of the epidemiological community do not unanimously favor the inclusion of social epidemiology as part of their discipline, sociologists specializing in the medical sociology subfield continue to carry out their work alongside physicians and medical researchers at local, state, and federal levels. While traditional biomedical epidemiology is considered a branch of medicine, many epidemiologists are, in fact, sociologists and other social scientists (just as many epidemiologists work in the field of social epidemiology within their own field). Some social epidemiologists favor conducting research themselves to the exclusion of social scientists (see Kaufman as one example[22]). Other social epidemiologists, such as Cwikel,[23] are not so quick to dismiss the value of collaboration with medical sociologists and medical anthropologists.

Regardless of their preferences, social epidemiologists incorporate traditional sociological variables into their research, including (1) social class, (2) gender, (3) race and ethnicity, (4) discrimination, (5) social networks, (6) social capital, (7) income distribution, and (8) social policy.[24] While many social epidemiologists prefer to conduct research focused on these types of conceptualizations to the exclusion of social scientists, most do not possess the training to do so on par with medical sociologists. Similarly, medical sociologists are not typically trained in medicine. Though collaboration, however, the strength of both disciplines can come to the forefront to produce groundbreaking research.

Thus, social epidemiology can benefit from sociological input. Sociologists generally acknowledge the various differences between the biomedical approach and the sociological approach. Brown provides a good characteristic sociological approach to social epidemiology.

> A core conception of this book is that *health and illness must be understood in a social context*. In the creation of disease and death, biomedical factors are often eclipsed by social factors. For instance, modern sanitation and improved living conditions are widely acknowledged to have been more important than medical advances in the modern decrease in the death rate. Even

> when we look at the effects of biomedical causes, social factors – such as race, class, and access to care – often result in differential rates of disease and death. Nor does medical knowledge alone provide sufficient understanding of the underlying causes of morbidity (disease) and mortality (death). For example, medical practitioners and researchers often fail to take into account environmental variables such as workplace and community toxic wastes. Nor do practitioners and researchers tend, for example, to focus on such phenomena as the correlation between mortality and a society's overall social inequities. Even social concepts which have arisen in part from within medicine – e.g., the role of stress in illness – are generally underutilized by medical professionals in explaining health status.[25]

Brown goes on to explain the proper place of social epidemiology in a medical sociological approach.

> As a field, epidemiology has not always been as politically conscious as medical sociology…epidemiology falls short because… it does not generally conceive of health and illness with reference to political, economic, and institutional structures. Thus medical sociologists have applied their insights to epidemiological questions, not in the interests of furthering epidemiology per se, but as a means of improving sociological analysis…A social epidemiological background allows us to examine some central forces in health and illness.[26]

The general approach taken by medical sociologists is to utilize an epidemiological approach to the extent that it assists them with understanding patterns in which medicine and society converge. Social epidemiology takes society and its institutions into account. Generally, then, social epidemiologists recognize the importance of social patterns in their overall approach to understanding biomedical causes and distributions of health and disease. They conduct epidemiological research within a social context.

1. The Debate Concerning Social Epidemiology

The question of whether social factors should receive greater attention by traditional biomedical epidemiologists has become controversial quite recently. One camp prefers to focus on pure biomedical epidemiology. They favor the exclusion of social variables as falling outside their field. Thus, many medically-trained epidemiologists disfavor social epidemiology.[27,28] One criticism relates to the fact that a significant percentage of the investigators' involved lack proper medical education and training. Most of these investigators come from the social and behavioral sciences.

The other camp prefers incorporating social and cultural variables. An increased recognition of the significance of social factors by those in the second camp has manifested itself as the promotion and development of social epidemiology – so this trend has moved forward despite the controversy. Therefore, other epidemiologists[29,30,31,32] do see the need for it.

While this debate continues, it is important to note that another consideration is valid as well. That is, physicians without proper social science training may not make good *social* epidemiologists. Again, a certain level of arrogance among some physicians clings to the unfounded idea that social science is not really science or it is somehow less scientific than medicine. Anyone who has studied human behavior even peripherally learns quite quickly that the various aspects of this focus are anything but simplistic.

Thus, all epidemiologists with medical training do not agree with the social epidemiological approach. Still, many in the medical community have recognized the importance of social issues as reflected by the emergence of *social epidemiology*. Medical sociologists incorporate a social epidemiological approach in their research when it becomes relevant to their research. In fact, they strongly emphasize the connections between biomedical and social factors in such circumstances. In contrast to "pure" epidemiologists, of course, medical sociologists recognize the importance of a social epidemiological component to their own research as they accept the connection between biomedical and social components and their interrelatedness. Medical astrosociologists will utilize a similar approach. The scenario preferred by this author would involve a strong collaboration between medical astrosociologists and those trained in space medicine.

2. Social Epidemiology Likely to Strengthen

The need for incorporating social epidemiology into the more established general field of biomedical epidemiology is becoming increasingly recognized.[33] Social and cultural factors are no longer ignored by all epidemiologists and they are more commonly understood as complex contributors to the predictions of health status and outcome factors.[34] The risk factors related to disease, as one example, occur within a social context and cannot be understood in isolation – that is, removed from society.

Due to the fact that social epidemiology finds supporters both among medical researchers/physicians and medical sociologists, it is likely that this approach will continue to strengthen over time. The controversy among epidemiologists will no doubt continue, but a significant number will continue to favor combining biomedical factors and social forces – or, viewed another way, favor studying biomedical factors in a social context. Sociologists who specialize in medical issues will continue to place a social epidemiological framework in its proper context as well, in essence concentrating on social and cultural forces that relate to biomedical factors.

Moreover, even social epidemiologists trained within medical organizations sometimes refer to psychosocial factors or even "psychosocial epidemiology" in an effort to acknowledge psychological factors that, in this instance,

receive even less attention than sociological factors.[35] It is clear that many researchers favor a greater infusion of social-scientific variables and totally reject a purely biomedical approach. These individuals could be quite productive if they collaborated with medical sociologists because it would bring together the expertise among those who work in two distinctive yet related disciplines.

C. Social Epidemiology in Space Environments

In space societies most notably, then, epidemiologists will need to acquire new skills that incorporate social factors into existing epidemiological analysis and practice requiring an interdisciplinary cooperation in health promotion and disease prevention.[36] The inability or, worse, the refusal to take psychosocial factors into account can quickly prove devastating the population of a space community. For example, if a particular widespread social pattern creates unhealthy conditions, then the concentration on purely biomedical factors could totally overlook the "cause" of an epidemic. In contrast, taking into account the combination of social and biomedical factors can isolate purely social risk factors as well as those that may be termed "biosocial" factors.

In a smaller population in isolation within the confines of a space habitat, an epidemic could wipe out an entire society in short order. It thus becomes that much more critical for epidemiologists to isolate the cause of the disease whether it turns out to be a behavioral form (e.g., a contaminated water supply) or a biological form (e.g., an airborne contagion). Based on past the occurrences on Earth, it seems almost inevitable that accidents will result in some sort of contamination or the escape of pathogens. Social epidemiology will prove an invaluable perspective in the sickbay. Lives, or the entire population, may be saved by identifying behavioral patterns before a medical diagnosis is possible – especially regarding space microbes or mutated ones brought from Earth into the physical environment. It is another good example of how physical/natural scientists and social scientists can, and should, collaborate. We must duplicate the collaboration between social epidemiologists and medical sociologists on Earth in space as a strong collaborative effort between space medicine researchers and medical astrosociologists.

Space societies will benefit most from an epidemiological approach if it is, indeed, a *social* epidemiological approach. Relatively small and isolated populations cannot afford to go through the same pattern of slow adoption, and continuing opposition, witnessed within the academic disciplines located in terrestrial social structures. With this in mind, it bears noting that medical sociology represents a broader subfield that includes social epidemiology as but one tool in its arsenal.

VI. Cultural, Social, and Ethical Considerations

Social-scientific concepts comprise the core of both medical astrosociology. This section examines many of these important factors that will impact on the populations of space societies and long-duration space missions in more detail. The conceptualizations addressed in this section represent mostly important *sociological* concerns due to the background of the author, though many of them also pertain to a social epidemiological approach and the other social/behavioral sciences. The basics of these macro-level concepts, necessarily discussed as generalizations, receive rather brief coverage intended to familiarize readers with them as they relate to medical astrosociology.

Culture (comprised of social values and other ideas, social norms, and material culture), in concert with social structures, combine to shape the general character of a particular society. Social values reflect what is good and cherished in a society. Social norms are the rules of behavior, or expectations, and they protect social values. But culture is not enough. Social structures consist of recurring patterns of behavior, and they make it possible for a society to have consistency over time. Institutions carry out the important functions for a society. They are guided by the dominant ideas of a society's culture and operate as formally-constructed patterns of behavior. Other recurring patterns based on topics such as inequality also exist.

A. Social Inequalities of Social Class, Gender, Race and Ethnicity, and Physiology

All societies on Earth are characterized by social inequality in a number of forms. Inequality in a society presents its minority groups (i.e., those with less social power) with a situation in which they have little or no access to social institutions. Many social resources are squandered when the majority group attempts to impose its will on minority groups while the latter group struggles to gain a greater level of parity. Results of the struggle often favor the majority group and become reflected in the operation of social structures, and they often discriminate imperceptibly. Institutional discrimination is therefore difficult to identify and thereafter reduce from the current levels.

While social inequality allows one category to exercise power over another, the overall condition of a given society in which it occurs is harmed. Traditional forms of inequality on Earth compromise a society's ability to maximize its greatest potential by denying one or more categories of people the opportunity to contribute their knowledge and skills to mainstream society. Society is deprived of any benefits that would result. In space societies,

this reality would prove more harmful due to the small population size. They would theoretically prosper most with the full participation of all their members. Minimization of social inequality should become an important preventive element of the planning for any long-term mission.

1. Social Class

A social class structure, as indicated above, provides differential delivery of health care to a particular population. On Earth, lower social classes have lower access to health care. Moreover, their quality of care lacks the feature of that experienced by individuals at higher class levels. As discussed earlier, their lower access often results in definitions of health and illness that tolerate a greater number of medical conditions as "healthy." Powerlessness among these individuals causes them to accept the system rather than challenge it.

The initial leaders of an expedition on a long-duration mission or those of a permanent settlement may seek to formalize their power over others. A question arises, then. Will a particular space society include in its structure social inequality similar to terrestrial social classes? Conversely, will its leaders consciously seek to establish a "classless" society? While such an achievement is impossible to maintain as the population increases, leaders can attempt to minimize its effects (or the differences vis-à-vis access to the health care system and other social institutions). At the inception of a space society, it may seem likely that equality favors the potential of its success. On the other hand, those who do the manual labor associated with the construction and maintenance of the habitat may be viewed from the beginning as "less socially valued or desirable" than societal leaders. Social inequality based on social class becomes stable structural patterns of society under such circumstances. They become part of the normal operation of institutions but often appear to be normal.

To prevent inequality in this form, the planners and participants will need to agree to accept a democratic system that becomes implemented right away once setting up the habitat in a space environment, and ideally during training.[37] This type of solution should include formal mechanisms to cope with those who seek to violate the laws and other social norms pre-established based on social values that hold democracy as socially sacred. Limiting the impact of the social inequalities of social class will require a difficult challenge for leaders who sponsor a space settlement as well as those who run the social institutions in such a settlement.

2. Inequalities of Gender

Sex refers to biological differences between females and males. Gender, in contrast, refers to differences between masculine and feminine. Gender is a social concept while sex is a biological concept. The interrelated influences of biology and society make the determination of causation problematic. Again, the social meaning attached to each sex determines whether a trait or type of behavior is consider masculine or feminine, the latter of which becomes the target of prejudice and discrimination due to its association with inferiority. Gender inequality refers to the social patterns of discrimination against women. Other forms of inequality, such as against race or social class, combine to favor or disfavor various subcategories of women.

One discriminatory pattern common in terrestrial societies involves the conduct of research on male physiology simultaneously with an inattention to female physiology. Girls and women typically receive male-tested treatments including the types and doses of drugs administered. Separate tests for women outside of those aimed at female-oriented illnesses have only recently increased due to activism by women's groups. In space, gender inequality may result in a great deal of harm in terms of the ability to maintain a viable genetic diversity should the females of the population suffer an excessive mortality rate. Thus, social forces can result in biological problems that endanger the population as a whole. Shortsightedness can result in disaster.

In the occupational sector, a small space society may lack the diversity necessary to carry out all functions required to service the population and the habitat. Initially, a greater amount of equality may prevail. Under these circumstances, the question arises of whether such a pattern can continue as the population increase. In other words, can an isolated society in space afford to discriminate against women while the population is too small to allow for the needed occupational diversity? Further, will discriminatory practices against women begin to appear once the population does allow for occupational diversity among the males in a population?

3. Inequalities of Race and Ethnicity

In general, physical differences of any type potentially result in inequality for members who belong to a social category to which a stigma is applied. Historically, skin color and eye shape that differ from the typical features of members of the majority group have typically resulted in discrimination patterns. New traits may emerge.

To avoid discrimination, it is not acceptable to exclude non-white citizens from joining a space society because that is, in essence, practicing discrimination. The American space program does not exclude non-whites as it violates a whole host of antidiscrimination laws and policies. As with gender inequality, resisting the implementation of the inequalities of race, ethnicity, and national origin (with its different cultural norms and values) presents planners and participants with a huge challenge that actually counters behavior in terrestrial societies.

In the medical institution, these patterns of discrimination become manifested as a decreased access to the health care system as well as an inferior quality of health care within care facilities. Like those who belong to social classes, the existence of inequality creates social conditions that tend to lead potential patients to adopt a lower standard for the state of being "healthy." The poor and other minorities receive inferior care, overall. In space, these patterns of inequality may impose themselves even in small isolated societies.

4. Inequalities of Physiology

On Earth, discrimination against citizens who possess physical disabilities exists, causing additional difficulties for those targeted. They have prompted legal norms (i.e., laws) to develop. In the United States, for example, the fight for equal rights in this area required a difficult struggle that continues in many guises today. In space and on non-terrestrial bodies, a given population may develop subgroups with differential physical characteristics. If one standard becomes defined as "normal" compared to others, social inequality will develop to the detriment of the "abnormal" subgroups. Although this is the same process that occurs with the other forms of social inequality, and reflected most strongly by inequality regarding disabled individuals on Earth, space environments may produce a new source for the unequal treatment of citizens in space societies.

As with other areas of inequality, those unaffected or those who possess "superior" characteristics will attach social meaning to various disabilities that devalue individuals who possess them. Based on the foregoing discussion concerning the potential for the alteration of human physiology due to radiation and lower gravity fields, one cannot rule out the real possibility of physical disabilities occurring along with new patterns of illness. How will individuals who develop these problems, or those born with them, fit into society? Will patterns of discrimination develop for reasons related to power, resource allocation problems, or something else?

5. Conclusions about Classical Forms of Social Inequality

Medical astrosociologists will want to study issues related to social inequality of all different types. While its minimization should become a top priority even before a mission blasts off the Earth, its elimination will prove impossible. Thus, the unique characteristics of the various forms of inequality that develops in a particular space society will require careful study by medical astrosociologists and others. Only then could policy makers combat social problems that develop, including in the guise of medical ethics, medical treatment, and health care delivery.

What type of societal structure will ultimately develop? Will it emphasize social equality or devise criteria to devalue certain members of the population. No particular outcome is predestined. The development of relations among different types of people in any society is based on a long series of social interaction that involve making of decisions of individuals along with the creation of social policies by government officials.

Social inequality based on these social characteristics will affect other issues discussed below and elsewhere in this article. It is important to state the fact that the same forms of inequality found in terrestrial societies will occur unless formal countermeasures are put into place to present them. While a utopian society in space may be unattainable as it has proven on Earth, a situation that greatly levels out the severity of disparities remains possible.

B. Social Institutions: Political, Economic, and Religious Factors

As already mentioned, a space settlement is actually a "space society." As such, an extremely important feature any space society centers on what types of institutions develop.[38] The careful and purposeful construction of social institutions will make social life much more bearable for inhabitants from the very beginning. The one thing to avoid, which was common in past discussions due mainly to neglect, involves allowing the social environment to "construct itself" in a random manner. This "solution" can easily result in the failure of the settlement even while the physical habitat continues to operate nominally. The following social institutions represent prime examples of the types of issues that demand attention. The medical institution will depend to some extent on how the other institutions function as they are all interrelated to one another.

1. The Political Institutions

Democracy should be instituted at some point as the population size increases. In the meanwhile, how does a population far from its home planet avoid the formation of a dictatorship? A military or quasi-military command structure may succeed greatly in getting the job done during the cruise and landing phases of a mission. However, it has proven an inadequate model for meeting all of the interests of a growing or otherwise large population.

These types of considerations are relevant to medical astrosociology in the sense that they relate to the priorities the governmental leaders develop as to the welfare of the citizenry. A democratic leadership is more likely to provide health care for all citizens than a dictator or elite ruling class. The latter are more likely to provide better health care for themselves, their families, government officials and workers, and close friends. The bulk of the population is more likely to receive an inferior level of health care.

As the settlement grows in size, will the political institutions organize themselves? For example, using the United States as a model, will social structures similar to state and local governments arise? If so, how will they

interact with the "federal" government? These types of issues require thought before construction of the habitat even begins. Political institutions can be socially constructed or they can emerge haphazardly.

The political institutions are important because they dictate the character of other social institutions such as education and the criminal justice system. For example, is universal education a priority? Is the criminal justice system oriented to fairly punish criminal and non-political deviants, or is it oriented to punish citizens who disagree with the political agendas of the leadership. If the latter scenario becomes reality, will citizens injured by law enforcement officials receive adequate health care? What about universal health care?

The practice of politics must compromise the needs of various institutions in the ongoing allocation of resources. The health care system can only receive so much of a share of these resources – and it is unlikely to receive the lion's share of resources. Nevertheless, in a harsh space environment, the sick bay will likely receive a greater portion of the overall budget than found in most terrestrial societies.

2. The Economic Institutions

Social class was already discussed. How individuals and categories of individuals relate to the various elements of the economic system is critical. In addition, individuals must often make choices about how to spend their limited resources. In a newly formed space society, it is unlikely than an abundance of resources will exist. Time away from work, or leisure time, is critical to a well-balanced social life. Planners will need to ensure that physical elements of the habitat encourage community (or group) activities. Establishing a sense of community will improve the quality of social life tremendously. Conversely, social life will become less tolerable should a large segment of the population isolate themselves in their rooms when not working.

Several additional questions require careful thought. Is capitalism a good model for a space society? Will it inevitably result in a black market as we see in so many science fiction movies? If not capitalism, then what type of system is best suited for this closed economy, especially in its early stages? How will a space society distribute resources, including access to health care? How much dependence of trade with terrestrial societies is needed, or warranted? The answers to such questions will help to characterize the economic institutions. They must not be left to chance as those who exercise political power can highjack and shape the system to their own benefit before the "masses" even realize what has occurred. As with all social institutions, planning and resocialization during training (before leaving Earth if possible) will prove critical.

3. The Institutions of Education

The educational process will need to continue in order to properly socialize and teach facts along with the special skills required in a space society. The primary educational institution is most vital in this regard because it provides the foundation for subsequent learning. It also provides a fundamental location for the socialization process in which the youth internalize their culture and develop their social self. Professional educators are best suited to provide the quality of schooling required once children of school age come into the population as a result of migration or birth.

The secondary educational institution is vital for continuing socialization, including preparation for adulthood and fitting seamlessly into the workforce and other social institutions. High school education can prepare some citizens for vocations that do not require college. Examples include habitat maintenance and food preparation.

Higher education provides the knowledge and skills for the entire range of occupations from more sophisticated vocational training to the professions. While more practical occupations may dominate in the early stages of a space society's development, the same professions common in terrestrial societies will emerge. Astronomers may provide a practical role from the beginning such as monitoring surrounding space for potential asteroids. However, other professions will enrich the society. Examples include physics and the arts. Even the most esoteric professions possess important constructive societal and personal properties. A space society should support all possible vocations and professions to the extent practically possible.

Adult, or continuing, education will very likely become vital as new adaptations to space conditions occur. An ongoing need will exist to document these new social realities and incorporate them into training and educational curricula aimed at adults in the space society. New social statuses may arise due to a need to provide a newly-emerged service or profession.

Training of physicians and all needed occupational statuses in subsequent generations will prove vital for the continuing survival of a space society. A small population especially requires a good mix of occupations as well as some level of cross training. Educators will prove vital to the ongoing survival of a space society. Immigrants from Earth can supplement skilled vocational and professional workers as required for a small population. As the society grows, it will become more capable of filling important status requirements, including those related to the medical profession as well as social epidemiology and medical astrosociology.

4. The Religious Institution

Unless a space society is formed around a single religious dogma, the religious institution will reflect a multi-religious social construction. Different individuals and subcultures will practice unique religious beliefs. Religious

groups can become a source of social conflict. This requires an early establishment of the norms that regulate how different religious values become incorporated into the social structure of society.

As experienced in terrestrial societies, some of these beliefs will prove incompatible with established medical practice and other elements of society. Here too, social conflict could occur, yet religion is something often overlooked. Ethical issues arise and require either the imposition of the state's dictate, a compromise, or the total concession to the individual's religious standards. For example, some people disfavor surgery or blood donations based on the tenets of their religion. The state may force an individual to accept a procedure or treatment "for their own good." Alternatively, the two parties may agree to state intervention only when the patient risks death by refusing assistance from the medical facility personnel. Of course, the third option, to refuse medical assistance, places the patient's fate in the hands of a higher power on which he or she depends.

A space society, like any other, may experience serious conflict due to religious disagreements. While suicide bombings are not very likely, injury may result from it. It will be important for the planners of a space settlement to address the religious dimension so as to minimize the risks associated with conflict that gets out of hand.

5. The Family

The family is vital for the interface between private and public social life. It is a primary socialization agency that helps young people develop the knowledge and skills necessary to cope with social life. A diversity of family structures will probably develop as the traditional nuclear family structure has lost much of its standing in terrestrial societies. How will a space society cope with a high diversity of family structure?

Within the family structure, members possess values associated with health care that differ from those of other families. Early on, settlers coming from Earth will bring with them standards they adopted in their own families in multiple cultures and subcultures. Training will help to reduce heterogeneity in this particular area, though overall, heterogeneity provides greater stability for any growing population. Similar standards of health and illness should prevail as much as possible to avoid disadvantaged family members from refusing to seek medical assistance when objectively necessary. Inequality often prevails at the family level. Can a newly forming space society avoid a high level of disparity among families? This question deserves attention by medical astrosociologists.

C. Inequality in Space-Based Health Care Systems

As the issues raised in this article demonstrate, health care institutions in space environments will become increasingly pertinent as the populations in space increase. While the reality of a large space society is rather far off in the future, it behooves us to begin thinking about these issues so we can develop and eventually implement them when appropriate. This exercise will also allow for a more reasoned implementation of institutions in smaller populated scenarios. It will allow us to think about how various institutions affect definitions of health and access to the health care system. The guiding principles developed during the early planning stages can affect social groups of all sizes and functions in positive ways once establishing the settlement.

An earlier example considered the scenario in which a critical, potentially terminal patient requires long-term care while a very limited stash of medical supplies exists in the sickbay. Does the health care system on Mars elect to treat the patient? Can it afford to do so? The isolated nature of settlements far from Earth will force officials to make difficult ethical decisions that pit individuals, family, and close friends against the good of the larger society. How will the various forms of inequality affect medical decisions? On the other hand, if the patient prefers to end his or her suffering, will they allow for assisted suicide?

Will medical insurance play a role (inequality) or will another system be employed? Will the leadership of a settlement or long-distance spacecraft implement a system that provides universal health care? How will the system change as the population size increases? What if the number and severity of health problems caused by the uniquely harmful space environment result in an unprecedented level of medical care required? Many such questions should receive careful scrutiny long before a space mission begins.

1. Social Inequality of Disability

The number of in-utero developmental problems could increase (using the United States as baseline). If younger members of the population are born with disabilities or begin to develop them at early ages, this would place a strain on the health care system. For example, genetic mutations from radiation may result if the insulating properties of the habitat do not prevent it from penetrating habitat walls. Those that result in illness or disability may jeopardize the future of a space society if the subpopulation composed of infants and children experiences a high mortality rate. Will abortion become a valid option in extreme cases? Controversial decisions will likely occur due to the difficult circumstances that will likely present themselves.

Because treatment of long-term illnesses and disabilities depletes supplies and demands the attention of medical workers, inequality may develop to reduce the impact of these costly developments. That is, elites and those close to them could well receive preferential health care that pours whatever resources become necessary into their treatment

while the same level of care is denied to others. When any citizen, or much worse – category of citizen – becomes evaluated as possessing less social worth than the general population, their general treatment, including their medical treatment, suffers even when the laws of their society prohibit discrimination on the basis of disability or any other trait. Society plays a large role in how people are treated, then, but this has larger ramifications for whether not a society will survive in a harsh space environment.

2. Ageism and other Gerontological Issues in a Space Society Population

In fact, the complications added by simply living in space will probably affect the youngest and oldest members of a space society most significantly. An important question regards how a particular space society's culture evaluates and thus treats its youngest and eldest citizens. The non-terrestrial environment will probably add new complications to the situation.

As mentioned earlier, a space society population characterized initially by middle aged individuals will soon become a population characterized by an aging population. The inevitability of disabilities increases as the population ages which results in the necessity for added medical services for this subpopulation. Ageism may result as one rather clumsy way to cope with the situation. *Ageism* is defined by sociologists as a form of inequality as negative feelings [prejudice] toward, and/or discriminatory behavior against, a person or group because of their age.[39] In most terrestrial societies, older people are targeted most often. Ageism affects social life in any society. A space society will not prove immune. As such, definitions of health and illness, as well as the delivery of health care, will become complicated to the extent that ageism pervades a social system (no matter where it is located), just like any other type of prejudicial/discriminatory pattern. Together, if severe enough, all the patterns of prejudice and discrimination create a social climate that tends to create a downtrodden category of people who do not experience the best their society has to offer. They do not receive the best from society and cannot contribute their best to society. Will a space society tolerate poverty as we do on Earth?

Other gerontological issues will require consideration. For example, where do the elderly fit into the larger structure of society? Will the larger culture see them as wise and valued or "washed up" and burdensome? Their assistance can be utilized as volunteers in medical facilities and other capacities, if the former types of social values prevail over the negative ones.

3. Architecture Based on Accommodation

The messy environments to which astronauts and cosmonauts have become accustomed on the space stations orbiting the Earth will not serve a permanent space society. The young, the old, and the disabled will require access to appropriate parts of the habitat free from clutter and other dangers. Thus, the designers of the habitat will need to design the architecture to provide a high level of livability.[40] Drug use may become common if social life becomes too unbearable for some people. A habitat may become rundown over time due to inadequate resources and/or too little supplies sent from Earth. Would the leadership of a space society under these circumstances devote limited resources to rehabilitation? If not, rampant drug use could place the society in jeopardy due to a decrease in the workforce. Perhaps some type of balance could be struck, but it would be controversial. Parents of those left untreated would probably be less than satisfied with such policies.

Medical astrosociologists will need to work with engineers and space architects to construct a habitat conducive to social needs. The physical structure will need to conform to the needs of the overall societal structure that includes institutions and other social structures. Daily hardships will only result in unhappy settlers and increase the level of social conflict as well as psychological and social problems. Medical facilities will need to be highly accessible and include a substantial emergency service system tied into the habitat's physical structure.

4. Access to Health Care

Can the space society afford what we generally regard as universal health insurance? Medical insurance of some type may develop. Will citizens have to pay for their health care? If so, the establishment of social inequality will be close behind, especially if a significantly unfair social class system develops.

The very possibility of a significant pattern of differential access to health care requires both preliminary consideration and subsequent monitoring. The logical provision of health care for all who need it represents a goal to which a fair, democratic society should aspire. It will not be guaranteed. Social values and other ideas, as well as practical concerns and limitations, shape patterns reflected in the health care system of particular society. In space environments relatively far away from the real-time impact of entities on Earth, unique patterns of discrimination will become entrenched in social structures without due diligence.

With limited supplies, perhaps even dwindling or exhausted, compromises between healthcare and the good of the society become unavoidable. Limited medicine and medical supplies could lead to rationing. Even with the best planning based on the best intentions, social inequality may inevitably find its way into space-based health care systems. The pioneer mentality probably has a limited application in outer space.

On the other hand, the planners of an adequately financed space mission or settlement may ensure a large initial inventory of medical supplies, medicines, and equipment. It may prioritize the use of *in situ* resources to manufacture additional items to replenish dwindling supplies. Regular shipments of additional supplies would help greatly, of course, as would the established of a trade agreement with various terrestrial sources once the settlement begins to function normally (following its initial set up period).

D. Summary Remarks about Social-Scientific Considerations

Space societies still seem like a long way from reality. Does it make sense to address them at this point in our space age? Is this premature? The negative answer to such questions is based on the fact that the issues presented here are extremely complex. They will require much thought, research, and debate for years to come before humans settle space to any meaningful extent. If we do not begin now, we will lack the preparedness required to settle space successfully even when the enabling technology becomes available. Medical astrosociology will address a number of complex interrelated forces from space medicine and astrosociology. The latter field includes sociology and all the other social sciences which involve many variables and their combinations. One example of this regards the *psychosocial* factors that are involved – an approach that considers the interactive psychological and sociological forces. Medical astrosociology is also relevant for contemporary space programs as it expands traditional human factors analysis to include the power of the theoretical constructs and research findings of the mainstream social sciences. Currently, space analogs such as submarines and expeditions to Antarctica provide the basic model for space settlements and crews. Hopefully, this discussion demonstrates that we need to examine how the interrelated parts of modern societies, such as social institutions, are applicable to social environment of space societies and long-term crews.

Regarding the emergence of social institutions generally, one must keep in mind that they will materialize whether or not they are constructed purposefully.[41] If allowed to emerge without planning, many of the social problems that exist in terrestrial societies will take root in the societal social structures as the combination of individuals who comprise the initial population bring their own cultural biases with them. The health care system that emerges without planning will not likely include the characteristics that best assure the highest quality health care. Medical astrosociologists who take an activist role in the planning process can help to minimize the negative consequences that would otherwise take root without their social-scientific expertise – as a utopian society is impossible to achieve.[42]

Social epidemiology will help clarify some patterns of behavior, especially patterns of illness. However, it is a limited approach. The theoretical models and research findings generated by medical sociology provide a more well-rounded approach to understanding medicine in the context of society. Still, because social epidemiology tends to involve researchers with training in biomedicine, they could productively collaborate with medical astrosociologists.

The solutions to health problems rarely involve strictly biomedical interventions. Moreover, problems associated with health care often correspond to one or more categories of the population rather than a particular individual. And often, the "patient" is not a person at all but the health care system itself. Members of a space society may elect to improve conditions if they disagree with any forms of inequality in the system. (Conversely, there may be those who encourage it because it saves resources). The point here is that health care occurs in the context of society, whether on Earth, on the Moon, on Mars, or anywhere else. The various forms of social inequality, for example, combine to affect all institutions. If social equality is a coveted value, then the laws and non-legal norms created for the space society must reflect it – and those with various forms of power should enforce it.

VII. The Rise of Medical Astrosociology

Given the problems human beings must face in their space environments as discussed in this article, it should be clear that the need for a social-scientific extension of space medicine undeniably exists. It may be viewed in part as a hybrid between medical sociology and space medicine due to the need to apply the unique elements of space environments with those of a space society or long-duration space voyage. Preparation for the problems and issues identified by space medicine coupled with those identified by medical sociology that occur in terrestrial societies will blend together into a unique manifestation of issues to be addressed by medical astrosociology. Even aboard the ISS and Mir, many of the social problems addressed here have presented themselves in serious ways that demand attention within very small crews.

Admittedly, "the rise of medical astrosociology" reflects a *call to arms* rather than a description of a historical trend already underway. Even so, the title of this section indicates the significance of sparking a new trend in the near future. The need to establish and develop medical astrosociology is vital for the very survival of large or small populations in space, just as the need for medical sociology and medical anthropology remain important in terrestrial

societies. The rise of medical astrosociology needs to commence immediately so we can lay out its framework and go about the business of conducting the research needed for the foreseeable future. Populations in space environments have not become large enough to warrant a formal collaboration. However, as humanity prepares itself to settle elsewhere in its solar system, both the development of medical astrosociology and then the establishment of a working relationship with space medicine will prove crucial.

Ethical issues arise during the practice of medicine, whether on Earth or beyond, so they require resolutions that take into account non-medical criteria. Depending on the decision-making structure of a particular space society, medical astrosociologists could offer options reflecting solutions to similar problems that humans face in terrestrial societies. Here, the work of medical sociologists becomes vital. It is important for medical astrosociologists to be familiar with theory and research in this subdiscipline. At first, it will probably prove vital for medical sociologists to work with space medicine physicians and researchers to develop the parameters of medical astrosociology.

Policy decisions concerning medical issues inevitably involve extensive, and often agonizing, compromises. Much of the ongoing work of medical astrosociologists in space societies will involve conducting research to uncover problems and patterns that prove both positive and negative. And, thus, it should be emphasized that medical astrosociologists should be present in these extraterrestrial social environments. As discussed previously, most of the concepts, theories, and research findings familiar to medical sociologists can be adapted easily to space environments, as can those from other subdisciplines that focus on deviance, political economy, the family, and religion. New theories and research efforts will need to expand to new areas of concern that are unique to space environments such as issues related to radiation, gravity, and the biological effects – and consequently the social effects – of such conditions.

A. Ties to Space Psychology

Space psychology has a history as long as the space age. Indeed, psychologists helped to select the "Mercury 7" astronauts as the United States sought to get into the human space race. The history of psychology in the Soviet Union's/Russia's space program, like America's, actually extends a bit before the beginning of the space age. Curiously, sociology and the other social sciences were not as influential as psychology. However, as humanity travels beyond low Earth orbit (LEO), psychology will remain important though its strong focus on the individual will prove unable to cope with the social and cultural issues focused upon by sociology and anthropology, though social psychology does focus on some of the same issues. Astrosociology has come onto the scene as a multidisciplinary social science field characterized by (1) a focus on human behavior in outer space and (2) the goal of becoming a collaborative partner for the space community.

While medical astrosociology will undoubtedly include psychologists and social psychologists in its ranks, the field of space psychology already exists. It is also likely that strong ties will develop between the two fields as medical astrosociology develops. Medical astrosociology exists for those psychologists of different backgrounds who favor looking at psychological issues in a social context. Each space psychologist will need to determine for him- or herself whether to adopt a medical astrosociological approach or retain the perspective of a space psychologist. The decision to retain the perspective of a space psychology will not affect the need to develop medical astrosociology. Space psychologists will need to work with medical astrosociologists to bridge the corresponding gaps between the two fields as well as cooperate in those areas that overlap. Psychosocial phenomena provide a good example of the latter type of focus.

The unique characteristics of space societies and long-duration space missions will produce new psychological conditions. In turn, these conditions will have the potential to manifest themselves as social patterns that will require interventions on scales that can greatly exceed one patient. In this and other ways, the social and cultural patterns that emerge will dictate that a segment of social scientists redirect their attention to space research, including the issues that fall under the purview of medical astrosociology. On Earth, the fields of medical sociology and medical psychology have a myriad of connections to one another. The same will prove true between medical astrosociology and space psychology, and members of both fields.

B. Medical Astrosociologists Needed

In the discipline of sociology, medical sociology represents a large subfield. On Earth, the social, cultural, and ethical dimensions of (1) definitions of health and illness, (2) medical care issues (including differential care quality), and (3) the delivery of, and accesses to, medical care have proven every bit as important as the purely biomedical aspects. In space, the same patterns will occur. The development of medical astrosociology therefore presents those involved with both space medicine and medical sociology (and other relevant fields) with a great challenge though its need will soon receive recognition as planner start placing people into their habitats in a serious way. Thus far, the construction of the physical habitat has garnered nearly all of the attention.

1. Medical Astrosociology in Educational Institutions

Astrosociology, generally speaking, currently resides outside of academia's formal structure. To date, there is no astrosociology program in the United States or elsewhere in the world. In fact, not even one *Introduction to Astrosociology* course exists, let alone an entire course dedicated to medical astrosociology. Because the goal is to develop astrosociology as an academic field, it is quite clear that this state of affairs is currently far from the reality that advocates seek. As with the STEM subjects – which focus on the natural/physical sciences, technology, engineering, and mathematics – the future demands that we bring outer space into social science classrooms to motivate those who will become social scientists to dedicate their careers to space research.[43] Medical astrosociology will develop only with this dual role of motivating natural scientists and astrosociologists; and humanity's ability to live in outer space will become enhanced in the process.

Will the first medical astrosociologists be educated and trained in sociology programs or medical programs? Will it occur in another social science discipline? It could well develop as a subfield of space medicine first. The first astrosociology course will likely develop in a social/behavioral science department or program. The best candidates are sociology, anthropology, or social psychology. Psychology represents a more remote fourth possibility. However, a program that focuses on space psychology may be a good candidate to offer a course in medical astrosociology. Those that combine disciplines, sociology and anthropology for example, or space research with social science may create an early medical astrosociology course.

A school of medicine that already includes a curriculum dedicated to space medicine may choose to offer a course or, later, even an entire program dedicated to medical astrosociology. This article focuses on the connections between space medicine and social-scientific inquiry, so such a development would make sense. The traditional emphasis on biomedical issues is incomplete. Thus, space medicine programs should view medical astrosociology as a complementary expansion of their current approach. Together, space medicine and medical astrosociology possess the potential to more comprehensively understand the medical issues by focusing on the interplay between biomedical and social-scientific issues rather than one dimension in near isolation of the other.

Space agencies such as NASA and ESA could adopt astrosociology – in fact, this is a major goal of advocates – so that they place pressure on educational organizations to offer astrosociology courses. NASA's *Habitability and Human Factors Branch*, part of the *Habitability and Environmental Factors Division* located at the Johnson Space Center, already considers social and cultural factors to a limited extent. It represents a fine example of a candidate organizational division that can benefit from the infusion of medical astrosociological concepts, theories, and research priorities. Other parts of NASA and the other space agencies around the globe could benefit as well once they begin to adopt medical astrosociology into their research and planning efforts.

VIII. Conclusion

As the first formal introduction to, and proposal of, medical astrosociology, this article could only touch sparingly on some of the major issues without going into the great depth they deserve. Nevertheless, the goal of demonstrating its significance is met without qualification. If nothing else, it should provoke thought about a neglected area of theory and research, and it should also provoke interest among some of its readers so they consider pursuing this new field. The future is now in the sense that we must prepare to deal with health issues in space *before* we send large populations into space. The lessons learned in smaller populations will prepare us to deal with the extraordinarily complex issues from both branches of science that humanity will confront in space environments.

We know too little about the physiological consequences of conducting long-term human space exploration and less about how to counteract them. More alarmingly, we know very little about the astrosociological issues that will present themselves during the course of human space exploration *and*, to complicate matters, we are doing very little to prepare ourselves. We must take an evenhanded approach that includes both the space community's traditional physiological and performance considerations along with the behavioral considerations of the social/behavioral sciences and humanities – the latter of which fall under the general purview of astrosociology when associated with space environments. Medical astrosociology belongs in the sickbay because human beings are involved. Decisions about health care delivery and access in specific situations will often involve messy details about which only a compromised solution beyond strictly biomedical considerations.

We must rethink the status quo that focuses almost solely on space psychology. We must expand our approach to incorporate astrosociology as whole and medical astrosociology in particular. NASA is a good candidate to take the first bold step in this inevitable direction. The sooner this takes place the better, so that we can begin to educate the first generation of astrosociologists. By doing so as quickly as possible, NASA can hire astrosociologists sooner so as to incorporate a strong social-scientific voice that complements both space psychology and engineering.

We know high levels of radiation, varying gravitational fields, and other physical phenomena have proven problematic for the human exploration of space and habitation beyond the Earth's atmosphere. Moreover,

> [t]he understanding and definition of space medicine will change as space travel and medicine change. Those changes must continually be kept in mind as visions and strategies for space medicine and astronaut health and safety evolve.[44]

The same must be stated about medical astrosociology as well. As they complement one another, a change in the physical realm nearly always possesses ramifications for the social realm, and vice-versa. Space medicine and medical astrosociology belong together in space environments just as (terrestrial) medicine and medical sociology belong together with societal structures on Earth. Physical changes are possible, but social changes are inevitable and can bring extreme complications to life beyond the Earth. We must heed these social forces – and the sooner we begin to do so, the better life in space will become.

Thus, the unhealthy nature of space environments coupled with the social and cultural ramifications of physiological changes make medical astrosociology relevant even now as we must begin to understand these ramifications as soon as possible. Furthermore, the transformations of our species into other forms, even if subtle – whether they are caused by nature or humans themselves, or a combination of the two – will have tremendous foreseeable and unforeseeable social and psychological effects on human societies in space. Issues related to social inequality and the proper use of medical supplies are just two general examples.

Space medicine cannot exist without social-scientific elements impinging on decisions made by physicians and medics embedded in a spacecraft's crew. Sociological, anthropological, psychological factors, as well as combined effects, will influence the decisions of medical personnel. For example, epidemiology traces patterns of disease within a population without the requirement to understand the pathogen or its delivery mechanism from a medical perspective. The rise of social epidemiology provides good evidence that a biomedical approach alone is inadequate even to properly investigate the causation of disease.

In fact, medical astrosociologists will need to work closely with physicians to make proper decisions consistent with the cultural values of any space habitat. Additionally, they will need to determine the acceptable risks involving whether or not to permit certain behaviors that may lead to injury and treatment that overly drains existing medical supplies (including drugs). Medical astrosociology is pertinent because space medicine involves human beings in space environments, human behavior is complex, and social and cultural patterns always impinge on otherwise straightforward medical decisions.

However, we must now begin thinking about placing medical astrosociology into the classroom so we may begin to train those needed to work as medical astrosociologists with knowledge about important issues such as social inequality and social epidemiology in space environments. To do so will require an extraordinary effort to establish medical astrosociology in various types of programs and departments in colleges and universities. The time has finally come for the involvement of the *other* branch of science in space research. For the first time since the abandonment of the Apollo program, NASA officials and those of other space agencies along with private corporations have begun to make serious plans for Moon bases and Martian settlements. Successful long-term plans will need to strongly consider social-scientific concepts and potential problems. Astrosociology, including medical astrosociology, can provide the needed balance once it is accepted as a legitimate academic field.

In closing, when all is said and done, this article serves merely as a first step. It was never intended to identify all the issues or especially to provide in-depth solutions to the problems discussed. Rather, the major purpose of this article is to demonstrate to the space community that the social sciences will prove indispensable to space exploration and settlement as (1) larger groups go into space; (2) they remain away from Earth for extended periods, or permanently; and/or (3) they become increasingly isolated from terrestrial societies due to the lack of instantaneous communications and/or distance. Astrosociology was created to serve as the multidisciplinary field with which the space community could collaborate. In the present case, this discussion of medical astrosociology serves to broaden the current approach to space medicine in a way that replicates patterns found in medical systems within terrestrial societies. Health, illness, injury, and medical care issues will prove even more extensive and complex than dictated only by biomedical concerns in the space environments in which human beings find themselves in the future. Interrelated social-scientific elements will require study and often intervention. Thus, we must develop the foresight needed to bring medical astrosociology into the sickbay *now* in order to ensure that we can properly address the multidimensional needs of these intrepid spacefarers in the future.

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