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Deviance in Space Habitats: A Preliminary Look at Health and Safety Violations

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Abstract

It is easy to take a well-functioning complex system for granted, even when we do not quite understand how it will work in great detail before starting it up for the first time, or exactly how it works thereafter (given its complexity). At the system level, the normal operation of the space habitat can result in accidents. On the personal level, complacency, and the false sense of security that comes with it, become the enemy quite quickly and usually without much – or any – notice. Workers do not intend to overlook important signs of behavioral aberrations or equipment malfunctions, but they may lose their sharpness and objectivity over time. In isolated settings, a variety of causes can result in devastating accidents, which may result in illnesses, injuries, and deaths. In the worst circumstances, within the confines of a space habitat or spacecraft, an entire population could be lost. Oil refineries provide a good, though obviously imperfect, analogy for the space habitat. Refineries are complex systems that transport and process oils and fuels at varying steps during the refining process within a complex system. Space habitats represent even more extreme closed systems. There is often no escape, as the habitat provides the atmosphere and other elements necessary for survival. Inhabitants of space habitats must avoid the types of accidents that have occurred in refineries on Earth if they expect to survive as individuals and as a social system. Submarines present a better analogy of a closed system. A challenge that never disappears relates to the possibility that the system may operate on a "normally" on one day and then malfunction on another day for no apparent reason. Another challenge among members of a space society is to avoid complacency, because an imminent failure may occur at any time. Yet another challenge is to avoid engaging in health and safety violations in order to serve expediency due to pressures exerted by superiors and for other reasons. Maintenance workers and others must also avoid succumbing to peer pressure based on a variety of rationales. We can learn much from the existing social scientific health and safety literature. Theoretical application of these lessons to space habitats presents a difficult task for the astrosociologist before we build these extraterrestrial physical and social structures. These findings need to become part of the planning process in the future, but we must understand them now rather than after we place human beings at risk in hostile space ecologies. This article takes an initial, and thus cursory, look at these issues related to one form of deviance, hoping to serve as an impetus to provoke future research into this largely unexplored area.

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1. Introduction to Deviance and Social Control

The violation of health and safety regulations is a form of deviance. In a space habitat, this can be an especially dangerous offense because it could result in severe injuries, deaths, and even destruction of part or all of the habitat itself. The potential construction of the physical structures are rather common (for example, see [1]), but the general area of deviance in space ecologies remains severely overlooked. This article takes a first important step toward addressing this particular important form of deviance. Because it exists in terrestrial societies, it is inevitable to exist in space societies within habitats. Under such circumstances, including the inevitability of the social phenomenon and the potentially extreme risks to human survival, one must conclude that it would be irresponsible to ignore this area of research.

A few quick definitions will provide the reader with a good background from which to understand other related issues. One may define deviance as the violation of social norms or expectations. Restated, deviance is the violation of social rules. In this case, the formal norms that comprise the regulatory environment exists to lower the risks associated with accidents and willful sabotage. Formal norms are written down in a rule book of sorts, whereas informal norms exist as unwritten verbal lessons that regulate behavior on a daily unofficial basis. Norms exist to protect or enforce values. Values inform members of the population of the difference between right or wrong among other things. In general, though, values tell the population what is valued in the culture.

Deviance is a relativistic concept. Its definition in a given circumstance depends on the audience that witnesses it, either directly as when the act is witnessed, or indirectly as when viewers of a television report learn of it, or when members of the criminal justice system learn about it after an investigation. How an act of deviance is defined by the audience is important to how various elements of a society react to it. In the case of health and safety violations, the opinion that a technical violation of a regulation is not actually deviant – or may be justified – can result in lingering hazardous conditions that result in an accident at a later date. Such a circumstance cuts potential applications of social control out of the process, as the initial investigation regarding the first violation never occurs.

Social control exists to regulate individual and group behavior so as to encourage conformity. The enforcement of health and safety regulations contributes to social order, but it also reminds people of the need and importance of the rules. A space habitat, like any other human ecology, relies on rules to define acceptable risks versus unacceptable ones. Enforcement of formal rules is vital in order to maintain an acceptable level of risk while simultaneously allowing for the completion of sometimes dangerous tasks. There is often a balancing act between defining acceptable risk and necessary risk. Such decisions come from the leadership of the space society, and citizens are required to observe them or face punishment. It is important to make clear, however, that social control includes both positive reinforcement, or rewards, for positive behavior and punishment for negative or deviant behavior. Leaders must utilize both tools in order to improve the likelihood that workers charged with ensuring safe operation of the habitat continue to do what is best for the entire population.

Thus, an important social value shared by all or nearly all of the residents is the belief in maintaining a safe and healthy habitat. Most individuals do not require the threat of punishment to follow health and safety regulations. They do so because they value a safe and healthy habitat. This is called "informal social control." The stronger the effectiveness of informal social control, the less often individuals need to be threatened or actually punished. Threats and actual punishment are known as "formal social control."

It is less effective. When applied too often, it is a sign that informal social control is not having its intended, and necessary, effect.

Health and safety violations occur constantly in terrestrial workplaces. Therefore, it is important to understand that deviance will occur in space just as it does on Earth. Planners of space settlements will need to put into place a well-constructed social system that takes this into account [2]. Thus, a criminal justice system, and other parallel administrative enforcement systems, will need to exist. The maintenance of an acceptable level of health and safety of the habitat will require scrutiny, and thus one cannot simply assume that it will exist just because of the probable severe danger that would exist otherwise.

2. Ties to Medical Astrosociology

This author introduced the subfield of medical astrosociology in 2008 as an effort to expand the definition of space medicine and related fields that have tended to neglect the influences of society – including their cultures and subcultures – on the practice of medicine [3]. Like any approach to astrosociological analysis, that of studying space habitats must concentrate on the human dimension. A central concept in this regard is that of *astrosocial phenomena*, or the social, cultural, and behavioral patterns related to outer space. By its very nature, this concept ties these social-scientifically-based patterns to the physical world in which they exist. Astrosocial phenomena relate to medical astrosociology in the sense that they complement the biomedical issues related to space medicine and related fields. They tie the social world to the physical world for matters related to space.

The definition of medical astrosociology is defined as the study astrosocial phenomena that affect medical issues in space environments [3]. This approach seeks to mimic terrestrial subfields such as medical sociology and medical anthropology in the context of space medicine. In contrast, medical astrosociology places the emphasis on issues of medicine and health issues, including the practice of medicine, in extraterrestrial environments. Space researchers and others will need to consider this approach because medical decisions are based on a much broader array of factors than exist in the realm of biological and medical knowledge. This specialty of astrosociology brings in the concept of astrosocial phenomena, as mentioned, and social scientific influences thereby become part of the central focus. Thus, medical astrosociology is the study of the interplay between biomedical and social scientific phenomena within space ecologies (*i.e.*, the social interactions that occur within the physical space habitat).

> 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 ([4]:4).

Cultural differences among patients, physicians, nurses, family members, and other parties add complications to the practice of medicine whether on Earth or in space [3]. Because each person possesses his or her own moral and ethical standards, reactions to physical injuries or illnesses are complicated beyond strictly "medical" decisions. When it comes to health and safety, moral and ethical standards affect decision makers, enforcers of regulations, maintenance crews, and residents of the habitat. They influence behavior among all parties, and thus it is faulty logic to depend only on the physical symptoms dictated by biomedical protocols.

How does medical astrosociology relate to health and safety violations? The obvious answer relates to the fact that medical personnel will need to respond to the potential consequences of health and safety violations. The health component is rather evident as disease is commonly treated in the normal course of medical practice. Treatment of injuries serves as another common challenge to medical professionals. Additionally, medical personnel must respond to emergencies when accidents occur. Severe injuries can place a great deal of stress on medical personnel. Beyond the obvious, medical astrosociologists should take on additional responsibilities. Medical astrosociologists should partake in the planning process. They should also be involved in the monitoring of behavior within the habitat just as social scientists observe human behavior on Earth. The social sciences serve an important purpose, and it matters little where the social settings they study actually exist, on Earth or beyond its atmosphere.

These facts, by themselves, do not answer the question directly, however. A large part of the answer relates to the idea that medical professionals should be part of the process of social control in order to establish a preventative environment within the habitat. The goal should be to prevent health and safety violations so that they do not result in injuries and illnesses that overwhelm staff or overly diminish precious medical supplies. Avoidance of catastrophic events is vitally important, of course, but a continuation of seemingly minor forms of disobedience can take a serious long-term toll. This is especially true of harmful exposures that go unnoticed until symptoms finally begin to show themselves among members of the population.

Space environments produce additional dangers beyond those experienced in Earth environments. Examples include harmful radiation, multiple gravity fields, and harmful or absent atmospheres. These forms of potential additional medical complications seem quite evident. However, the social and cultural problems associated with them often exist without notice or careful consideration. In combination, they may result in dangerous outcomes not possible in more benign Earth ecologies. Violations, whether based on omission or commission, can produce additional forms of danger that threaten technological systems and/or people because of these interactions characteristic of space environments. Therefore, planners need to consider these interactions when planning to build a habitat in a particular space environment. The space environment is an important "actor," just like the human actor.

One question may come to mind when first thinking about health and safety violations in space habitats. Why should anyone spend time studying health and safety in the space habitat so far in advance of the construction of the first facility? This type of question is fair to ask because, to many, it seems like a waste of time given humanity's current limited presence in the solar system. In defense of the current effort, an argument can be made that it is prudent to understand health and safety violations in space habitats because it takes a rather long time to establish a good body of knowledge about any understudied subject matter. Moreover, the study of analogs that have implications for life and work within the habitat are too important to ignore as we move ahead to study other aspects of the space habitat.

Thus, rather than a waste of time, the study of health and safety violations in the space habitat will provide planners of the physical and social elements with an invaluable arsenal of theoretical and practical knowledge that will result in a safer and healthier ecology. Moreover, based on the importance of analogs, there are implications for terrestrial ecologies as well. Several technologies, procedures, and enforcement techniques developed for future space habitats will prove themselves useful in dangerous workplaces on Earth, including in undersea habitats. Regarding the latter, we have already witnessed that undersea habitats can also have important applications for space habitats. NASA periodically sends crews to the permanent undersea habitat known as *Aquarius* as part of its NASA Extreme Environment Mission Operations (NEEMO) project. The lessons learned in such exercises are directly and indirectly applicable to the physical design of space habitats and the construction of social environments within them.

3. Defining Additional Pertinent Concepts

Before turning to other conceptual discussions, it is important to operationalize several key terms in order to ground them to recognizable and measurable terms. In this way, theoretical discussions to follow will become more understandable to the reader, especially to those lacking previous knowledge in this area of study. This is valuable because considerations related to health and safety violations in space habitats do not yet comprise a familiar area of study, though some of the concepts defined here are rather commonly discussed and well researched in the social science community. The difference here is that discussions of these familiar topics involve health and safety ramifications in space environments, so some extrapolation becomes necessary.

3.1. Defining a "Confined Space"

The concept of a "confined space" is relevant in *terrestrial* settings when workers must toil under conditions that restrict their freedom or comfort in some way. Governments create definitions and associated regulations aimed at allowing work in confined spaces to occur with reasonable limitations on risks. The American and Canadian definitions to follow serve as two good examples of terrestrial-oriented approaches. These types of exercises involving identification of risks and establishment of regulations to mitigate them must become part of any planning for space habitats.

The Federal version of the Occupational Safety & Health Administration (OSHA), part of the United States Department of Labor, provides the following description of a confined space.

> Many workplaces contain spaces that are considered "confined" because their configurations hinder the activities of employees who must enter, work in, and exit them. A confined space has limited or restricted means for entry or exit, and it is not designed for continuous employee occupancy. Confined spaces include, but are not limited to underground vaults, tanks, storage bins, manholes, pits, silos, process vessels, and pipelines. OSHA uses the term "permit-required confined space" (permit space) to describe a confined space that has one or more of the following characteristics: contains or has the potential to contain a hazardous atmosphere; contains a material that has the potential to engulf an entrant; has walls that converge inward or floors that slope downward and taper into a smaller area which could trap or asphyxiate an entrant; or contains any other recognized safety or health hazard, such as unguarded machinery, exposed live wires, or heat stress.

The Canadian Centre for Occupational Health and Safety (OSH) provides the second definition of a "confined space."

Generally speaking, a confined space is an enclosed or partially enclosed space that:

- is not primarily designed or intended for human occupancy
- has a restricted entrance or exit by way of location, size or means
- can represent a risk for the for the health and safety of anyone who enters, due to one or more of the following factors:
  - its design, construction, location or atmosphere
  - the materials or substances in it
  - work activities being carried out in it, or the
  - mechanical, process and safety hazards present

Confined spaces can be below or above ground. Confined spaces can be found in many workplaces. A confined space, despite its name, is not necessarily small. Examples of confined spaces include silos, vats, hoppers, utility vaults, tanks, sewers, pipes, access shafts, truck or rail tank cars, and aircraft wings. Ditches and trenches may also be a confined space when access or egress is limited.

Thus, space habitats are confined spaces in the strictest sense, because they do in fact consist of enclosed spaces, which is a fundamental element of their definition. Space habitats are closed systems because they present residents with a permanently enclosed structure in which they must live, and rely upon, for their very existence. They represent the entire living space for all inhabitants. There is no getting away from it and into wide-open (or unconfined) spaces, as even the sands of Mars exist in an environment that lacks a breathable atmosphere. Space environments present human beings with hostile conditions that completely surround them.

Furthermore, the dangers inherent in a space habitat do conform to some of the ideas of terrestrial confined spaces. Examples include the potential to introduce a hazardous atmosphere (or the loss of one), and thus potential asphyxiation of inhabitants, heat stress, and limited entry/exit points do exist. Furthermore, the Canadian definition points out that the term "confined space" does not necessarily refer to a small size as a limitation. In essence, then, one may think about a confined space in the present context as an structure that limits the free movement of individuals from the ability to easily travel in the larger local space environment. On Earth, for example, one may escape a sewer system filling with noxious fumes by simply returning back to the surface. In a space habitat, a large population may not have anywhere to go that is safe beyond the space habitat.

On the other hand, these descriptions pertain to terrestrial working conditions intended to be temporary in order to get a short-term job accomplished. Confined spaces are defined in terms of dangerous working conditions in which the objective is to quickly resolve some problem or make a repair as quickly as possible. The definition of the common terrestrial confined space does not involve living in a confined environment on a permanent or long-term exposure to ongoing risky conditions. Thus, space habitats do not involve the types of *temporary* working conditions expressed above regarding terrestrial locations. Instead, they present workers or maintenance crews with a constant state of eminent danger. Assuming that architects and engineers planned and constructed the habitat following reasonable health and safety specifications, physical environments away from Earth present potential though less eminent risks on an ongoing basis with the potential of these low-level risks becoming life threatening on a number of different levels at any time.

Outside of the space habitat could lie the vacuum of space or a toxic atmosphere of a planet or moon. It differs from a structure such as a terrestrial house because the outside environment cannot support human life without space suits or other life-saving equipment. In conclusion, the concept of confined space reflects an important backdrop to remind us that the space habitat itself restricts its inhabitants to living within its walls. The space habitat is, in fact, the ecological niche that shapes the relationship between the humans living with it and the physical structure itself. The space habitat is their immediate environment. It is a *closed system* for most inhabitants because they have no interaction with the outside environment. Therefore, proper maintenance and repair potentially serve a more important purpose. They serve to ensure the survival of the inhabitants.

3.1.1. Defining Complex, Closed Technological Systems

In sociology and other social science fields, scientists study organizations that depend on ongoing oversight and maintenance of complex technological systems in order to ensure their proper functioning. Complex systems such as oil refineries or nuclear power stations consist of sophisticated technologies that maintenance personnel may not quite understand fully. Nevertheless, they are required to operate them and keep them in reasonable working order despite pressures, both internal to the person and from external sources.

A problem that often arises is that emergent properties resulting from the complexity of all the divergent parts add unpredictability to the operation of the complex system. Because the space habitat must function properly to keep inhabitants alive, it must be comprised of a great number of subsystems, themselves consisting of heterogeneous parts that make up the whole. Ideally, planners, engineers, and other experts possess a theoretical understanding of how the system will function before they build it. However, there is no way to be completely certain of its performance – and its unique quirks – until they build the system and it comes online. And even then, unknown and thus unanticipated interactions occur that result in accidents due to what Perrow [4] has termed “tightly coupled” units; that is, connections within the system that we often overlook. A potential problem of complex systems is that they may not exhibit aberrations until years after activation, so maintenance personnel must stay alert in case something new and unexpected occurs. Moreover, it is quite possible for entire technological systems to fail rather than individual parts. A constant monitoring of the overall system is necessary in order to prevent a major catastrophe. For the residents of a space habitat, such an event could result in the loss of the habitat and them along with it as the worse-case scenario.

When a complex system is also a closed system – such as a submarine or space habitat – the task of maintaining a safe ecological system becomes even more difficult. The system needs to provide ongoing life support as well as a host of other functions. When something fails, a quick response time can save lives since most residents have nowhere to flee. However, the complexity of the system provides a sense of unpredictability that can result in catastrophic accidents as witnessed at terrestrial workplaces. Health and safety violations can worsen already dangerous complex, closed systems by adding even more complications. The human component complicates such issues even more from a multiplicity of different statuses (*e.g.*, maintenance worker, average inhabitant, health and safety inspector, medical personnel, and government official). They all have their own input into prevention, reaction, and reporting responsibilities that affect health and safety in the habitat, which adds additional uncertainty into an already complex equation.

Health and safety risks are unavoidable in complex systems. Failures may result from violations of regulations or seemingly unavoidable breakdowns in the system. The fact that a complex, closed technological system such as a space habitat depends on continuous uninterrupted operation in order to ensure survival of its inhabitants leaves very little room for error. Technologically, redundant systems can avoid overall failure of the whole system. Socially, interactions among people at various levels of the social hierarchy, including those between health and safety personnel and others as well as those between people and machines, are often overlooked by engineers and others, but they nevertheless impact the system. Psychologically, various motivations and additional personal factors may cause individuals to violate health and safety standards on a consistent, intermittent, or rare basis. Therefore, it is important to take into account the fact that all interactions potentially contribute to the level of health and safety in the habitat, and the human dimension is critical – as it is a crucial part of the technological system.

4. Ecology vs. Environment

Although the concepts of ecology and environment are too often used incorrectly and therefore interchangeably, they are not the same. In general, the term "space environment" refers to surrounding conditions outside of the space habitat. The immediate or local environment refers to the physical location – the confined space – alone without any regard to the human dimension. This physical environment defines the space habitat with no regard to the society within. In contrast, the term "space ecology" refers to the interaction between the physical environment in a particular location in space (or off the Earth) and the human population that lives there [5]. This distinction is important because an ecological system ties the physical environment to a human population (or the social environment).

In the current discussion, this means a relationship exists between the human population and the interior of the physical space habitat, in addition to the environment outside of the habitat. The ecological system within the habitat's walls defines where the inhabitants live and most of the health and safety violations occur. Thus, the nexus between the physical environment of the space habitat and the social environment that includes the social structures and interactions within the habitat defines the ecology of most interest here. The internal environment and social environment are tied together to form the ecological relationship between the physical and the social worlds. The space society exists within the physical habitat, but the two are intrinsically bound to one another.

Of course, the ecology under question is subject to influences from the larger local space environment. For example, radiation may affect physical systems of the habitat and lead to health problems among the citizens of the space society. Proper health and safety regulations and their implementation require monitoring of such external threats, so the exterior environment plays a vital role as well. Various types of impacts, both long-term and short-term, can impinge on the integrity of the habitat and its systems. Health and safety violations can occur outside of the space habitat if proper maintenance does not occur. For example, a regulation may require exterior inspections of various parts of the habitat. Violations still exist if compliance to these types of health and safety regulations does not occur since ignoring scheduled procedures can easily result in increased dangerous conditions.

5. Defining the Space Habitat

For our purposes, the definition of *space habitat* is a permanently closed technological system in which a population of human beings lives and which provides all of the necessary conditions, both physical and social, to survive on a permanent or long-term basis. Inhabitants may, of course, leave the habitat for short periods of time, but they must return eventually to their permanent structure. Three of the most important characteristics involve permanence, dependence for survival within the structure, and provisions for protection from a hostile environment outside of the habitat. This definition is somewhat more expansive than some existing definitions because a space habitat can be a space station, facility on a planetary body, or a spacecraft on a long mission such as a generational spaceship. One important key to this definition relates to the fact that space habitats exist to provide protection from a deadly environment on the outside while simultaneously supporting a livable human ecology on the inside.

This confined space represents the ecological setting for the citizens of the settlement. Because this confined space must keep them alive for a long-term period, or even a permanent basis, since no breathable atmosphere exists outside of it, this article makes certain assumptions about the space habitat for the purposes of this discussion. Because the citizens of the habitat have voluntarily committed to permanent residency or had no choice in the matter due to some unforeseen circumstance, the residents of the habitat have the obligation to make sure that the living conditions are both survivable and livable at a comfortable level. Written rules must exist to protect habitat inhabitants and the integrity of the habitat. Actions and inactions that violate these standards constitute health and safety violations, and thus they require both reactive and preventive strategies.

A space habitat is unique compared to most places or social settings in which humans live, work, and recreate. A few similar terrestrial examples come easily to mind such as submarines and Antarctic bases. However, even these analogs do not define a permanent situation as even submariners receive a leave after a predefined tour of duty and both examples involve a rotation of crews. A permanent space habitat offers no release from the enclosed environment. Permanent residents of a space habitat may depend on its proper functioning for their entire lives.

As one would suspect from the foregoing discussion, the ecology on the inside is the main focus of astrosociologists. Once again, however, it is not the only focus. For example, excursions outside of the habitat and into the hostile space environment may bring forth astrosociological issues such as teamwork or incidents of conflict among two or more colleagues. In fact, all aspects of the interaction between human beings and their habitat – the very definition of an ecology – fall within the purview of astrosociology. Moreover, the social interactions that occur within this ecological system are somewhat unpredictable, as are the interactions between people and machines, so they can result in accidents leading to injuries, exposures, and even deaths. Thus, planners must construct a health and safety system, both physically and socially, and inhabitants must operate it faithfully on a long-term basis in order to ensure success of the space society.

6. Defining the "Space Society"

Like a terrestrial society, a space society implies an organized population living within specified "borders" that shares a common culture that includes a set of values, other ideas, and material culture as well as social institutions designed to carry out important functions for that society's everyday tasks. This author first defined the term "space society" in 2006 in order to offer a social-scientific perspective on human populations living in space. The following is the current definition:

> [A] *space society* is defined as a space colony/settlement in which members of the population (1) share a common culture, (2) live within a closed physical environment, and (3) cooperate with one another, social groups, and institutions in order to meet the social needs of all its citizens. A space society may be small or somewhat larger. However, the greater the population size, the more impersonal the social system. It becomes characterized by more secondary groups and fewer primary bonds ([2]:4).

Some researchers have termed small groups of space residents as members of micro-societies or mini-societies. These terms emphasize the small population, with the former smaller than the latter. However, their small size has implications for other matters such as the organization of the social system, types of social bonds that become established, and various cultural issues. Individuals must be cross trained out of necessity due to their small group size, and they therefore have multiple skill sets that make response to a variety of situations possible. These circumstances are untenable over a long period of time, and thus they result in greater hardship for all involved. Due to practicality, an overly small population of ten or fewer members almost inevitably characterizes a temporary or short-term mission rather than a long-term space society.

As on Earth, a small group or community structure cannot sustain a growing population, nor can it accommodate the needs of a large starting population. Communities are homogeneous in nature, while space societies need to be heterogeneous by nature with a larger population size. There needs to be a high division of labor – including statuses and roles that support a health and safety regime. From a social-scientific perspective, then, mini- or micro- societies represent a poor model for long-term sustainable social systems, though most and probably all of the early space settlements will be comprised of crews, micro-societies, or mini-societies.

And while this article is based on the idea of a space society with adequate formal health and safety regulations in place, the current discussion is still relevant to smaller and less well organized groups living in space habitats. Many of the same health and safety concerns, and related issues, will exist in any size group living in an enclosed and isolated mechanical enclosure on the surface of a planetary body or in depths of outer space. The difference is that smaller social structures will tend to include fewer formally organized health and safety regimes.

Further, one may conclude that a space society is, in fact, a "risk society" due to the potential hazards that inhabitants face on a daily basis [6]. The incredibly reliable technological system needed to keep a massive space habitat functioning over a long time period almost ensures breakdowns and other problems. Coupled with health and safety violations, the advanced space society would require an extraordinary system of physical and social controls to ensure its longevity. A sizable proportion of its citizenry would probably need to dedicate itself to the various issues involved with health and safety. Thus, as humanity advances toward larger and more complex technological – and social – systems in space, the attention to health and safety issues must keep pace.

7. Defining the Concept of a "Health and Safety" System

A healthy and safe environment within the habitat is the major concern. The habitat must continue to function properly so that the population inside continues to live comfortably with minimal risks of becoming ill, injured, or killed by a malfunction by the system or an act by a human. The concept of "health and safety" exists in terrestrial environments to ensure that workers do not suffer "needlessly." Thus, one may define a "health and safety system" in the context of the space habitat as a social structure dedicated to maintaining the integrity of the space habitat and thus to protecting the vitality of the inhabitants. Health involves avoiding illness and disease of body and mind. One may consider this applicable to the idea that the two factors associated with health involve illness and disease prevention and then treatment following the onset of one or the other. "Safety involves two factors – accident prevention, and damage mitigation after an accident" ([4]:163). An additional element is the implementation of new measures that address old inadequacies.

As with other forms of deviance, health and safety violations are not always intentional. There are (1) unintentional errors such as those that include slips and lapses as well as mistakes that involve errors of judgment or decision-making and (2) intentional errors that include routine violations, exceptional violations, situational violations, and acts of sabotage (Introduction to Human Factors). All forms of violations involve patterns, so prevention and detection are both possible in some cases. Monitoring and statistical analysis of past patterns can make this possible. This is important because all forms can lead to serious consequences. Yet the very definition of "accident" implies that an unpredictable component related to health and safety exists. Thus, while preventive strategies can help avoid accidents, others arise without warning and require well-planned reactions.

This unpredictability has implications for how one defines violations of health and safety regulations. For example, an unexpected danger that arises based on an untested combination of interactions among the system's various parts may make it necessary to respond in an unconventional manner that happens to violate existing regulations. While the action violates existing standards, it may also save the habitat from damage and human beings from injury or death. How does one react in this situation? It points out the need for discretion in defining and reacting to technical violations. Deviance is a complex phenomenon that is subjective and often does not fit neatly into the definitions found in the rule book. There are aggravating and mitigating factors to consider, as well as other factors that create conflicting definitions such as differences related to subculture and social class. Thus, defining deviance is more of gray area rather than one consisting of a dichotomy such as "black or white," or "right or wrong." The same act viewed simultaneously by two people may result in one person viewing it as conforming behavior while the other views it as deviant behavior.

Ongoing maintenance requires vigilance in order to ensure that human lives are rarely endangered needlessly. Thus, negligence is always a factor when operating a complex total system over a long period of time. For one thing, complacency may set in due to a variety of factors, including familiarity [4]. Because accidents are uncommon, vigilance tends to wane over time. It may seem counterintuitive, but smooth operation over a long period may result in behavior that does not change, does not adjust to new circumstances that arise because no one expects them to occur and no one notices warning signs when they finally arise.

7.1.1. Accidents as Normal Occurrences in High-Risk Environments

Health and safety violations often result in accidents, many of which are unexpected. This type of pattern raises the question as to why they occur

> If interactive complexity and tight coupling – system characteristics – inevitably will produce an accident, I believe we are justified in calling it a *normal accident*, or a *system accident*. The odd term *normal accident* is meant to signal that, given the system characteristics, multiple and unexpected interactions of failures are inevitable. This is an expression of an integral characteristic of the system, not a statement of frequency. It is normal for us to die, but we only do it once. System accidents are uncommon, even rare; yet this is not all that reassuring, if they can produce catastrophes ([4]:5).

Accidents occur as part of normal organizational functioning. The fact that they are uncommon is no reason to believe that they will not happen. "Tight coupling" refers to the strong interactive elements of the complex technological system. It includes various parts of the physical or mechanical elements, but it also refers to the human beings that interact with them. Together, the physical and social subsystems comprise the entire system, and both are extremely important [2].

Sagan [7] has contrasted Normal Accident Theory (NAT), which he supports, to High Reliability Theory (HRT). Among other things, HRT assumes that accidents can be nearly eliminated if a strong effort is put forth. In contrast, NAT assumes that "no matter how we try we will still have accidents because of intrinsic characteristics of complex/coupled systems" [4]. La Porte [8] has challenged Sagan's contention that NAT and HRT are in competition with each other and argues they are, in fact, complementary. Of course, we should always strive to prevent accidents and this can be effective to some extent. However, it is probably true that HRT is more appropriate and predictive of simpler workplace environments while NAT is more appropriate for complex technological systems such as space habitats. It is therefore best to remain as vigilant as possible because normal accidents will eventually occur, probably not all are preventable, and their occurrences require quick and effective responses after they occur, whether they wreak havoc or only take the form of health and safety violations that harm no person or machine.

7.1.2. Health and Safety Violations as Normal Events

Since accidents occur as part of normal organizational functioning, and health and safety programs are built into the system, do health and safety violations also occur as part of normal organization functioning? Can this type of deviance become normative even while it threatens the lives of the violators and the entire population alike? The answer to this question is – surprisingly – "yes." There are many reasons why this is the case, including "bending the rules" over a long time period, but the important point is that it is possible. All societies exhibit deviance. The health and safety system is thus indispensible in order to ensure survival, and more importantly, sustainability for the habitat and its inhabitants. The problem is that it may not always accomplish its mission. Consequently, updates of the health and safety system result in a more stable space habitat, just as improvements of various aspects of the physical system help to accomplish. New insights about "normal" violations require various types of adjustments throughout the overall system.

8. Considering analogs

When considering health and safety violations in future space habitats, it is important to consider how they manifest themselves in similar terrestrial social settings. Knowledge gained from analogous situations can aid in the planning of both new physical and social systems, including considerations of their interactions [2, 9]. While a brief discussion of several analogs serves to acquaint the reader with some of the benefits of considering them in the context of health and safety in space habitats, a more detailed treatment is required as it falls outside the purview of this article. A few examples follow.

Mines are not complex technological systems per se, but they are confined spaces. We have seen deadly accidents and mine closings based on many of the same issues that we expect to exist in space societies enclosed in airtight habitats. Mine accidents have been caused by workers, policies of management, and seemingly unforeseeable conditions that arise. Perhaps the most important lesson besides the need to carefully plan for as many contingencies as possible is the devastation that can occur to equipment and people when a failure of any type occurs.

Submarines are closed, complex technological systems while under water. Everything needed to sustain human life is onboard with the submarine crew. While submerged, the outside environment is just as deadly to humans as living on surface of Mars. The most significant difference between the two is the fact that submariners have a good chance to surface in case of an emergency while inhabitants in a space habitat are too far away from a breathable atmosphere. Those living in space habitats must cope with emergencies as they arise without the luxury of an escape scenario for a large population.

Arctic/Antarctic bases are not closed, complex technological systems, but they can provide insights about social interaction in isolated places. The technological system is not quite as complex as a space habitat, but it must keep the inhabitants warm and keep scientific instruments functioning among other things. The isolation can cause behavioral anomalies that provide important information to researchers. However, like submarines, the people there have a good chance of rescue even though they may have to wait a considerable amount of time during an emergency, as when a storm sets in.

Oil refineries and chemical plants are not closed systems although they provide important clues about the dangers of complex technological systems. Nuclear power plants, like oil refineries, represent dangerous complex technological systems. Their study as complex technological systems can add knowledge to the requirements necessary for a successful space habitat. Accidents and exposures to toxic chemicals that occur in these types of systems can provide important lessons for future planners.

The study of space habitat analogs already exists, of course, but considerations of health and safety violations are not normally part of that research. In general, the study of deviance in space habitats remains low on the priority list of researchers. For the reasons elaborated in this article, however, this needs to change. Astrosociologists specializing in the fields of deviance, health and safety violations, and organizations can collaborate with scientists and others in the space community to gain a much more complete understanding of these issues through collaboration on a formal basis.

Finally, we can learn from older, simpler space habitats as new ones are planned and constructed. This is a good model for space stations with rotating occupancy as well. Of course, the International Space Station represents the best contemporary approximation to a permanent space habitat. Along with the psychological studies taking place among astronauts, the study of deviance can provide invaluable insights for future research in the area of health and safety violations.

9. Issues Of Health And Safety In The Space Habitat

As within any enclosed or confined space, the functioning of the subsystems rendering the space habitat fit for human survival must continue operating indefinitely for a permanent settlement. Deviance related to health and safety makes this task ever the more challenging because violations occur for different reasons, many of which simply overlook any impact they have on the level of risks. Under these conditions, which exist in every known complex organization, the leadership must take action to minimize needless escalations of risks and therefore minimize avoidable accidents. For the residents, a livable standard of subsistence represents the mandatory standard describing the living conditions within the habitat. Simple survivability is untenable.

9.1. Ethical Concerns Related to Health and Safety Conditions

Ethical standards may range from lax to very strict. Setting the highest possible ethical standards regarding health and safety conditions is a good idea, of course, but other considerations may compromise ideal conditions. For example, as related above, complex systems may cause unpredictable failures to an extent that risky behavior is necessary to repair them. Maintenance workers may take shortcuts in order to make their work less demanding or because they lack the correct parts to do the job correctly, as well as a host of many other rationales. They may make such decisions on their own, they may do so under orders, or they may even take actions under misguided perceptions of what their superiors expect.

Assuming that the population living in the confines of the space habitat is large enough to comprise a space society rather than a smaller social system such as a mini-society, micro-society, or crew, then stratification issues may arise in the most striking forms. Inequalities due to social class, gender, race, ethnicity, religion, and other criteria may well make some parts of the habitat less healthy and safe than other parts [9]. Relatedly, responses to emergencies may not be the same for all citizens or sectors of the space society. While most people do not expect life in the space habitat to approach a utopia, a shared culture that supports the minimization of undue risks can improve health and safety conditions without a great deal of reliance on threats and punishments by the leadership. For several reasons, then, forging a single larger culture provides benefits to the population, regardless of the fact that a multitude of subcultures will also coexist.

9.1.1. Other "Enemies" of Health and Safety Standards

Threats to health and safety standards may arise from a number of different places and for a number of different reasons. This topic can fill the volume of a book without much trouble. Therefore, only a short discussion of a few of the most significant causes of health and safety violations is appropriate here.

Conflict between management and labor in terrestrial corporations is built into the capitalist system leading to worker alienation and potential resistance [10]. Max Weber [11] focused on the negative effects of bureaucracies on workers. Many other sociologists also addressed such issues, as all societies feature various forms of social inequality including social class and other forms of social stratification. Thus, the types of institutions constructed – such as the economic and political systems – will definitely affect social conditions and thereby affect health and safety conditions, as will other various elements of culture and society.

Thus, problems can be initiated from the top. The leadership may have agendas that favor other priorities even above ensuring a healthy and safe environment. Under ideal circumstances, a separate non-political entity would exist to monitor violations initiated by leaders of the space society as well as others in higher statuses. This division of labor is not practical for a small population, however.

Problems instigated from the bottom of the social hierarchy can contribute to unsafe living conditions as well. Often, violations are not purposeful. Complacency is an important threat that may result in devastating consequences even while those empowered to maintain safe health and safety standards regard their efforts as satisfactory or even meeting high standards. Additionally, because workers' incorrect assessments of management's expectations can easily result in resistance, including violations [12], ongoing training can help keep workers and supervisors on the same page over time. Another cause of violations occurs when maintenance workers do not feel that the leadership is treating them properly. Resentment can lead to violations, and even sabotage, as already stated.

People are a part of the complex system. Their behaviors alone can cause an accident, but sometimes it is based on an interaction between the physical and human components – the physical/human interface – that occurs during routine procedures. Accidents can be based on normal organizational operations that seem safe due to the fact that they have not resulted in accidents in the past [4]. Again, complacency and a false sense of confidence that current practices seem adequate to protect the habitat can result in situations in which a new combination of factors comes into play. If they are not recognized, the assumption will continue to support the idea that all is well, just as it was yesterday, last week, and six months before. Fighting this tendency is crucial to uncovering new systemic changes as they occur.

Inadequate training or drilling can cause workers and civilians to react inappropriately during emergencies. The absence of a quick and effective emergency response system can add to the tragedy. Ideally, everyone must also know how to obtain competent emergency medical care as part of such a system [13]. They must know how to react to intensifying risks when they witness them. Sudden and long-term dangers such as the loss of atmosphere or exposure to toxic contamination must have protocols for dealing with them. All inhabitants of the space habitat should be constantly weary of threats to their well-being. However, uncertainty among the members of a threatened population will normally result in disjointed action [14]. Therefore, ongoing education programs will prove vital, as civilians are not always aware of all of the threats they face. That is, their perceptions may not always coincide with objective reality in all situations.

10. Enforcing Health and Safety Regulations

In the United States, the Occupational Safety & Health Administration (OSHA) – part of the Department of Labor – was created in 1970 to monitor workplaces and "to ensure safe and healthful working conditions for working men and women by setting and enforcing standards and by providing training, outreach, education and assistance" (http://www.osha.gov/about.html). Such an approach, which involves positive preventive techniques and preventative reinforcement as well as negative reactions to violations, is a sound overall system of enforcement under ideal conditions.

Maintaining a safe and healthy space habitat requires a reasonable level of enforcement. Based on problems encountered in terrestrial workplaces such as oil refineries and mines, one must expect violations of health and safety regulations and thus a well-thought-out system must exist to cope with them. It is not a question of if violations will occur; it is a matter of when they will occur and what forms they will take.

The fact that enforcers should use discretion in evaluating and reacting to violations of regulations cannot be overemphasized. Just as utilizing self-defense in a situation in which a human being dies is not considered murder, saving the habitat from failure by disobeying health and safety regulations is not always a violation of the spirit of the affected regulation. Human beings live and act in social settings that involve often complex circumstances. All of these circumstances require evaluation before a proper reaction can take place. Sometimes a health and safety violation is not a violation based on the situation. Discretion allows for a reasonable assessment and reaction that is impossible if one simply follows the strict interpretation of the rule book.

Sometimes, the violation of health and safety violations does not result from purposeful action. For example, lack of proper sleep may result in workers making uncharacteristic mistakes when dealing with repairs. How do leaders address such circumstances? Does punishment do any good in these situations? Should punishment be less severe compared to purposeful violations? The answer to the last question is that those in power to enforce violations do in fact make distinctions based on the evidence. Those in charge must consider mitigating factors. At the same time, the findings of investigations into health and safety violations, whether purposeful or not, should always be scrutinized in order to prevent similar problems in the future.

In a space habitat, there is usually no option to shut down facilities that violate protocols if such equipment operates to make the habitat survivable. This is why engineers and maintenance staff require redundant systems. Thus, flexibility is important to ensure survival. Similarly, the enforcement of health and safety regulations must tailor itself to include practical considerations that go beyond simply a strict interpretation of the rules. In this case, flexibility allows for enforcers sometimes to err on the side of ensuring a well-functioning habitat over the punishment of violators. Enforcement must have a purpose. Health and safety regulations exist to protect the successful functioning of the habitat and the related protection of human life. Punishment is one means to achieve this goal, but it is not always the best choice because positive reinforcement is usually more effective in the long term.

The best form of enforcement does not come from the regulators or health and safety inspectors. Instead, it comes from the average citizen. Informal social control – based on a strong set of values that exist in the larger culture that favor a healthy and safe habitat – represents the best way to minimize unreasonable risks and void devastating accidents. Remember that social values are ideas in the culture that tell us what is valued as well as the difference between right and wrong. Ceremonies that reward citizens for positive actions can serve to strengthen and reaffirm norms (*i.e.*, social expectations) and protect associated values. If the average citizen strongly supports a healthy and safe habitat, then the formal type of social control that we equate with punishment in its various forms is required less often. Citizens are more likely to report dangerous conditions and, probably more importantly, less likely to contribute to them when they internalize these values and their associated norms. Because deviance is a relativistic concept, it is best when citizens, inspectors, managers, and everyone else views health and safety violations as deviance rather than inconsequential or even justifiable behavior.

11. Conclusions

The issues included in this article are not completely addressed due to the lack of space allotted here. Nevertheless, the purpose is to familiarize the reader with some of the major ideas involving health and safety violations in the space habitat so that astrosociologists and others can begin to think about an area of study that remains ignored even while it presents us with a potentially devastating impediment to the successful operation of a space society on a long-term basis. Most of us may think that is incomprehensible for a worker to violate health and safety violations that may endanger human beings or the space habitat. Nevertheless, experience in terrestrial social settings have proven otherwise. Therefore, we cannot afford to ignore this set of issues.

The application of occupational health and safety concepts to life in a space habitat may seem misplaced. After all, these residents do not work twenty-four hours per day. They enjoy off time and they sleep approximately eight hours per day. So, why take this approach? The answer lies in the nature of their ecology. These residents depend on a well-functioning enclosure to keep them alive, safe, and healthy. After all, violations of health and safety regulations could theoretically result in a major catastrophe. When viewed in this way, a space habitat is equivalent to life in a dangerous workplace on a twenty-four hours per day basis. Thus, construction of a regulatory system and the enforcement of health and safety regulations seem quite sensible.

This focus on health and safety violations in space habitats adds another example to the growing list regarding why the astrosociologists must participate in the study of space issues, including planning of necessary social environments, and in the formulation of space policy. In the end, health and safety regulations depend on four fundamental elements: (1) the norms and values among leaders that shape informal health and safety standards, (2) the formal regulations that dictate the level health and safety, (3) the effectiveness of enforcement efforts, and (4) the cultural climate among workers and residents in terms of support or rejection of regulations and/or their enforcement. Thus, the functioning of the habitat is not the only issue. Social-scientific analyses serve to bring light to issues likely ignored by other scientists, yet they will prove of tremendous value to them in collaborative efforts. This article provides preliminary insights into problems likely to emerge in space habitats. Understanding them at this early stage will allow for the construction of ecological systems that involve proper combinations of physical and social elements of the ecology that complement one another, include built-in mechanisms for responding to – and resolving – health and safety violations, and allow for improvements to the overall system as time passes.

Space habitats must function properly for humans to survive on a sustainable basis. The original engineering and construction of the habitat is very important, of course. However, long-term sustainability requires that humans keep the habitat functioning in conjunction with automated systems (which also require monitoring). Thus, the structure must maximize both livability for the inhabitants and the ease of repairing its internal and external systems. This initial limited review of some of the major issues involved in living in space habitats emphasizes combining the physical and social structures involved in maintaining health and safety standards. The concept of astrosocial phenomena ties the human dimension to the environment of the space habitat, thus revealing the ecology that exists – something that must become the focus of both physical/natural scientists and social/behavioral scientists interested in this topic. Ecologies involve the relationship between a physical environment and human beings, so the interaction between the physical and social worlds must remain the focus. Future research must expand these ideas while keeping humans as the central elements in the design and construction of space habitats. It must focus on initial living conditions, but also include analyses involving long-term social life within the habitat.

11.1. Recommendations

Deviance will undoubtedly occur in space habitats, just it does in every terrestrial ecology throughout the world. The following recommendations follow from the previous discussions. These steps are necessary to help ensure the long-term inhabitation of a space habitat by a sizable population, an assumption of this exercise from the outset.

1) Recognize the fact that the planning of space habitats must include provisions for preventing, identifying, and reacting to deviant acts of varying types.
   a) Be prepared to cope with health and safety violations.
2) Do not forget about the human component during decision-making.
   a) Leaders should be prepared to cope with worker resistance (Roscigno and Hudson, 2004).
   b) Construct the physical habitat with systems that alert inhabitants, including health and safety officers/personnel, of accidents and continuing risks.
   c) Keep in mind that complex social/technological settings result in complex behavior patterns and thus may require creative solutions.
   d) Make the system flexible from the beginning as rigidity fails to change with the times.
3) Create mechanisms to reward citizens for positive actions regarding health and safety.
   a) Contrarily, avoid dependence on formal social control as the main instrument of conformity.
4) Make education and training a priority.

a) Establish an anonymous system for reporting health and safety violations and potentially unsafe or unhealthy conditions.
b) Train all inhabitants to recognize and react appropriately to unhealthy and unsafe conditions.
c) Continue a retraining program throughout occupancy of the space habitat because reinforcement of health and safety regulations is just as important as redundancy in technological systems.
d) Ongoing education and training should reflect lessons learned from past incidents.
e) Include average citizens in seminars and drills.

5) Based on the foregoing discussions, researchers should initiate the study of health and safety regulations in space habitats.

While these recommendations become more critical in certain ways as the population increases, they also have implications for smaller populations. Lessons learned from previous habitats with smaller population sizes can be applied to larger sized habitats as they grow. They represent objectives to which we should aspire as habitats become more technologically and socially complex over time. Health and safety violations in particular, and deviance in general, represent important areas of study for astrosociologists and anyone interested in the human dimension of space habitats.

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