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PRESERVING POSSIBLE MARTIAN LIFE

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As we expand our presence in the solar system, novel and challenging scientific and policy issues will face us. A relatively near-term issue requiring attention involves questions regarding the *in situ* human search for and discovery of primitive extraterrestrial life—Mars being an obvious candidate. Such a search and potential discovery is clearly of paramount importance for science and will pose unique and complex mission planning and policy questions regarding how we should search for and interact with that life. This paper will explore the scientific, mission planning, and policy issues associated with the search for and interaction with possible primitive extraterrestrial life, with an emphasis on issues regarding the preservation of such life.

Some of the questions to be considered are: To what extent could effects of human presence compromise possible indigenous life forms? To what extent can we control those effects (e.g. will biological contamination be local or global?) What are the criteria for assessing the biological status of designated locales as well as the entire planet (e.g. can we extrapolate from a few strategic missions?) What should our policies be regarding our interaction with primitive forms of extraterrestrial life?

Central to the science and mission planning issues is the role and feasibility of applying decision theory, risk analysis, and modeling techniques. Central to many of the policy aspects are issues of value. Exploring this overall issue responsibly requires a holistic understanding of how both of these dimensions of the issue interrelate.

1. INTRODUCTION

The primary emphasis of this paper will be on forward adverse effects with respect to the first human presence on Mars since such effects (in the form of contamination concerns) regarding robotic exploration have been reasonably well addressed. (However, contamination issues regarding robotic exploration may still require attention and are inevitably intertwined with an overall human mission planning strategy as indicated in Figure 2-1, Mission Planning Decision Tree for Preserving Possible Martian Life From a Human Presence.) This paper will also briefly address the policy and underlying philosophical aspects regarding the preservation of possible extraterrestrial life.

Before proceeding, however, it will be useful to first establish, in a general way, the need for addressing this issue. Such a need can be generally derived from three sources: (1) international law, (2) scientific value, and (3) public interest.

1.1 International Law

Regarding international law, Article IX of the United Nations Outer Space Treaty of 1967 states:

> States Parties to the Treaty shall pursue studies of outer space, including the moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination...and where necessary, shall adopt appropriate measures for this purpose.[1]

In addition, Article VII of the Moon Treaty of 1984 clarifies and improves upon the more general obligations of the Outer Space Treaty by stating:

> In exploring and using the moon, States Parties shall take measures to prevent the disruption of the existing balance of its environment, whether by introducing adverse changes in that environment, by its harmful contamination through the introduction of extra-environmental matter or otherwise.[2]

Interestingly, the United States, while a signatory to the Outer Space Treaty, is not a signatory to the Moon Treaty. However, the Outer Space Treaty and Moon Treaty have been interpreted by some to apply to non-signatories.[3] Unfortunately, both treaties are quite general, lacking specific standards as well as formal international mechanisms for enforcement.[4]

In 1983, after having gathered more data about Mars and the solar system in general, NASA moved away from the previous probabilistic standards for planetary protection procedures and adopted a less rigid policy involving five categories of missions and associated planetary protection requirements. There is no category addressing human missions. This may be because it is thought that once a human mission is underway, forward planetary protection will not be relevant.[5] Also, human missions to the planets are not a near-term concern. However, this paper will indicate that such a category may be required sooner than later partly because an important requirement of such a category will likely involve obtaining some understanding of the biological status of a given locale or the entire planet via a complex series of strategic robotic precursor missions—possibly numbering in the hundreds or more—for which long-term planning might be required sooner than later. There will also be issues of back-contamination that would most certainly warrant a planetary protection category for human missions that return astronauts and samples—similar to what was done with Apollo.

1.2 Science

Although the preservation of extraterrestrial environments is important for scientific knowledge in general, a primary concern of planetary protection is to ensure the integrity of life-detection experiments by minimizing the chance of a false-positive result.[6] The NASA Viking mission of 1976 is the paradigm example. Each lander had three life-detection experiments and was heat sterilized and encapsulated in a bioshield that was released upon arrival at Mars.

Underlying these concerns, of course, is the widely acknowledged importance of discovering the second data point that biology is so desperate for. This places a high value on preserving and avoiding masking possible indigenous extraterrestrial life due to terrestrial contamination.[7] The National Academy of Sciences Space Science Board (SSB) writes: "…Forward contamination…is a significant threat to interpretation of results of *in situ* experiments specifically designed to search for evidence of extant or fossil Martian microorganisms", and that protecting Mars from terrestrial contamination so as to not jeopardize future life-detection experiments is "profoundly important".[8] In a report on back contamination, the SSB also writes:

> It will be important to stringently avoid the possibility that terrestrial organisms, their remains, or organic matter in general could inadvertently be incorporated into sample material returned from Mars. Contamination with terrestrial material would compromise the integrity of the sample by adding confusing background to potential discoveries related to extinct or extant life on Mars. DNA and proteins of terrestrial origin could likely be unambiguously identified, but other organic material might not be so easily distinguished. The search for candidate martian organic biomarkers would be confounded by the presence of terrestrial material. Because the detection of life or evidence of prebiotic chemistry is a key objective of Mars exploration, considerable effort to avoid such contamination is justified.[9]

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However, some suggest that contamination concerns are unfounded. In his recent book, *The Case For Mars*, Robert Zubrin suggests primarily three reasons for why back contamination should not be an issue—and presumably the essence of these arguments apply to forward contamination as well. One, Mars and Earth have exchanged much material already. Two, life almost certainly does not exist on the Martian surface. Three, the co-evolutionary dependence of pathogens and hosts makes it impossible for Martian and terrestrial organisms to adversely affect each other.[10] These are reasonable suggestions, but it may not be that simple. The fact that material has been exchanged between our planets does not mean that contamination has occurred in the way it could with a significantly more intrusive mission (i.e. a human mission) to Mars. Also, if panspermia has occurred, then Martian organisms could be genetically compatible with new organisms that arrive via contamination, hence calling into question Zubrin's third claim that a lack of co-evolutionary dependence should mitigate contamination concerns. Secondly, the lack of existence of life on the surface cannot be known with confidence until we conduct more missions to explore the planet. The recent announcement of water on the moon, tantalizing evidence of sub-surface liquid environments (perhaps water) on Europa, and possible evidence of biological remnants in a Martian meteorite indicate how unpredictable our solar system can be. Even if we were to confirm that no life exists on the surface of Mars, there is, as Zubrin himself acknowledges, the possibility of sub-surface life—which should still be of great concern since our intrusive missions could contaminate the sub-surface of Mars via drilling and other activities.[11] Surface or subsurface life could also be adversely affected by toxic substances, predation, competition, and general environmental modifications, making infection with its co-evolutionary dependence only one consideration among many.[12] Lastly, we only understand one kind of biology. How confident are we, or can we be, that life on Mars will be consistent with our present understanding of life when we really only have one data point?

1.3 Public Concern

There is also the issue of anticipating and addressing public concern. As there have been in the past, there will be public interest groups attempting to ensure that NASA and other space agencies are not only doing what is perceived to be environmentally/politically correct, but perhaps morally correct as well. Species preservations groups will have a new cause to champion, and it should be assumed that they will not hesitate to act as an obstacle if they have any reason to believe that the proper precautions are not being implemented. Environmentalists opposing the use of nuclear power sources have been able to delay launches in the past. In this light, planning now to address the questions posed in this paper could help mitigate future opposition to sending humans to Mars.[13]

2. STRATEGIC MISSION PLANNING TO PRESERVE POSSIBLE EXTRATERRESTRIAL LIFE

Figure 2-1, Mission Planning Decision Tree for Preserving Possible Martian Life From Human Presence, is a preliminary attempt to frame the issues regarding long-term planning for a human mission to Mars—primarily with respect to the issue of forward contamination. An underlying assumption of the decision tree is that the scientific value of preserving extraterrestrial life is high enough that many in the science community would agree that these questions are worth pursuing, and possibly high enough to justify a fairly conservative mission planning approach as suggested by the decision tree. This section will step through the decision tree and make a first order assessment of the questions posed.

The decision tree poses a series of questions with respect to the issue of minimizing adverse affects on potential indigenous extraterrestrial life due to a human presence on Mars. Before touching on those questions, it is important to establish what it is meant by contamination. The Task Group on Planetary Protection of Space Studies Board, in their report, *Biological Contamination of Mars: Issues and Recommendations*, concurred with a previous NASA report[14] that "forward contamination more broadly defined to include contamination by terrestrial organic matter associated with intact cells or cell components" since such material is a "significant threat to interpretation of results of *in situ* experiments specifically designed to search for evidence of extant or fossil Martian microorganisms."[15] An even broader relevant definition of contamination includes non-biological elements such as new compounds from rocket exhaust or airborne pollution from industrial chemicals.[16] With this broad definition of contamination in mind, we can now consider some important mission planning questions as shown in Figure 2-1.

To what extent will there be contamination? This question has been addressed in a preliminary manner by Chris McKay and Wanda Davis. The thinking expressed in their paper is that contamination is inevitable if humans are present.[17] To pursue this with rigor, however, we should try to establish *the extent* to which there will be contamination since the amount and kind will likely be critical to decision making. If contamination possibilities are thought to be negligible, a human mission will not, and should not, be prevented from occurring as soon as it is feasible—politically and technically.

If it is thought that there could be contamination to levels that are deemed significant, we must then ask: *Could such contamination compromise indigenous life-forms?* A conservative answer to the question is yes, it is possible. But again, this requires substantial analysis. What is the probability? Is it even feasible to establish such probabilities with any confidence? What kinds of effects could there be and to what degree? While co-evolutionary dependence seems important, and may even be essential for organisms to effect each other, how confident can we be that this "principle" of terrestrial life applies universally given that we base this idea on one biological data point? So we might want to assess the relative probabilities of direct adverse effects given panspermia vs. a separate origin. Is the latter a probability of zero? The Space Studies Board says no.[18] What are the chances for indirect adverse effects via toxin production or competition for resources? For example, perhaps various life-processes could be more efficient with different chiralities characteristic of other life forms. What is the probability that non-biological elements such as rocket exhaust or industrial chemicals could compromise indigenous life-forms? Given that a single kind of life-form on earth might have caused the extinction of all others early on in the evolution of life, could such a scenario occur if foreign organisms are brought to Mars?[19] If we obtain an appropriate level of confidence that contamination will not adversely effect possible indigenous life, then GO!

Otherwise, we should ask: *Could such contamination mask the existence of indigenous life-forms?* A masking effect, if possible, will presumably have a dependence on whether or not the contaminating organisms are dead or viable, either as dormant or active organisms. Dead organisms will probably not have a significant masking effect for life-detection experiments based on life processes such as metabolism—as were the Viking mission experiments. However, dead organisms might have a masking effect for simple observation based detection devices such as microscopes and robotic life-detection devices—although with humans present, detailed analysis could be done that might mitigate this problem. While perhaps not the most likely scenario, we might consider that dead terrestrial organisms, after having been on Mars for some time, will not be recognizable as terrestrial organisms. For example, there might only remain fragments of organisms or the organisms might undergo some sort of physical modification, making it difficult, if not impossible, to rule out an indigenous source. It may also be very difficult to tell whether or not the resident organisms were deposited by the mission or whether they arrived via panspermia—an important scientific question in its own right. If we're confident that masking effects are not significant, then GO!

Otherwise, if we determine there is an unacceptable chance of masking possible indigenous life, we should ask: *To what extent can/should/will we control contamination?* The "should" and "will" part of this question are both important for a realistic assessment of the outcome of this decision point. That is, we may determine that we *can* control contamination effectively, but that perhaps, for various reasons, we shouldn't; and even if we think we should, an honest assessment should prompt us to consider that ultimately, other forces could prevail, resulting in an absence of contamination control. Whether or not we *will* actually control contamination is a legitimate and interesting question. It is legitimate because we often don't do what we think we should do. It is reasonable to suspect that many people who think we should control contamination, will also think that, ultimately, because of our exploitive, destructive, and selfish nature, we will not.[20] This leads to why the question is so interesting because it goes right to the heart of humanity's power to control its destiny. These are obviously complex issues that cannot be addressed here with the attention they require, but they will be touched on briefly during mention of the policy challenges represented on the decision tree, as well as during later discussions of the larger philosophical context of this issue. For now, we will concern ourselves with the more practical issue of the feasibility of contamination control.

At least one person has suggested that absolute containment of all terrestrial biology is, in principle, possible and even desirable over the less certain method of obtaining all the relevant planetary data to determine that contamination will not cause adverse effects. Joseph Sharp rightly points out that an entire technology has been developed to contain dangerous biological agents, and that while such an effort for the first human Mars mission would be quite expensive, in the long run, it may be the only sure approach as long as no failures occur.[21] The back contamination containment procedures for the Apollo Astronauts could be a useful starting point for addressing forward contamination containment issues of the kind suggested by Sharp. However, given the expense and absolute requirements of such an approach, it is worthwhile to consider the implications of the more realistic suggestion made by McKay and Davis that contamination is likely if humans establish a presence on Mars.

If, however, there is a reasonable chance for controlling contamination, the difficult problem is to assess *the extent* to which we can control it. While Apollo did not have rigorous containment procedures for preventing the contamination of the lunar environment, some steps were taken to reduce and inventory such contamination. For example, a bacterial filter system on the lunar module was used to prevent contamination of the lunar surface when the cabin atmosphere was released.[22] NASA also adopted as official policy, aseptic subsurface drilling, decontamination and contained storage of waste materials, and biological and organic material inventory requirements.[23] Understanding the amounts and kinds of contamination that are released into the Martian environment will be important for dealing with this overall issue. Will we be able to completely isolate a given locale, in which contamination controls could be quite loose? Or will we want or be able to rigorously contain contamination for all areas and activities? If we're confident about contamination control, then GO!

If not, *will contamination be local or global?* McKay and Davis have briefly touched on this question by suggesting that biological contaminants such as human bacteria may not survive

Martian oxidizing surface conditions and ultraviolet radiation exposure. However, we should consider the possibility that dead or viable organisms could potentially be distributed over a significant distance, perhaps globally, since large, sometimes global, dust storms are known to occur.[24] Indeed, McKay and Davis acknowledge this possibility when they say that "regions distant from the base may receive a lower bioburden."[25] The likely non-viability, and hence insignificant spread of contaminant organisms on the surface, while reasonable as a first order assessment, should be analyzed with as much scientific rigor as possible, paying close attention to the *continuous* source of contamination due to a human presence, possibilities of subsurface contamination, and other sources of contamination.

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If it is thought that contamination will be local, *what are the criteria for determining the biological status of a designated locale?* It may be prudent to assume that contaminants will at least be present and possibly viable over a designated locale where humans first land; so it will be important to understand what will be required to obtain confidence about the biological status of the locale in question, since contamination could compromise possible indigenous ecosystems. Robotic precursor missions and possibly tele-robotic missions from an on-orbit station or moon to a potential landing site are obvious ways to remotely obtain knowledge about the biological status of the locale. The interesting challenge is to determine what level of confidence we require and what kinds and numbers of missions will be needed to establish that confidence. Understanding subsurface possibilities will be critical since a human landing site will likely result in contamination of the top few meters of the soil.[26] If this is the case, drilling missions, or at least subsurface penetrating missions, seem to be obvious candidate precursor missions. These missions could be similar to the penetrator missions being planned for execution in the next few years with the crucial difference being that life-detection experiments need to be present and, of course, functional after experiencing high impact forces. It should also be acknowledged that a human base will probably have the ability to drill to considerable depths below the surface (possibly to or below the permafrost level) for both exploratory and resource prospecting reasons (e.g. searching for water), which could possibly result in contamination of an otherwise protected subsurface environmental niche. It seems this is a reasonable activity to expect the first human mission to engage in, and so sterilized robotic precursor missions may also be required to drill to comparable depths in order to assess the biological status of the subsurface environment for a certain designated locale where humans will first land.

Another important element for sending humans to Mars, as shown on the decision tree, is to establish a Human First Detection Policy for the search for and potential interaction with an extraterrestrial life-form. Search and post-discovery protocols will need to be established, presumably by the international community under a body such as the United Nations Committee on the Peaceful Uses of Outer Space (COPOUS)—perhaps via the Committee on Space Research (COSPAR). Should a remote reconnaissance of some locale from an established base be done before sending humans out into that targeted area? To what extent should a continuous and rigorous search for signs of life be conducted while humans expand their presence on the surface? What will be the de-contamination requirements and procedures for humans interacting with the Martian environment? If drilling is to occur, to what depth, for what purposes, and how will the associated contamination risks be mitigated? We have had some experience dealing with this kind of isolated environment on earth, and presumably, similar requirements and procedures would be applicable to Mars, as well. Additional potential threats to indigenous life such as mechanical disturbances from rovers and moving equipment that might disturb and expose previously protected niches and additional seemingly benign environmental factors such as water, heat and light should be studied and incorporated into policies for how humans will interact with the new environment.

Regarding post-discovery policy, what will we do when we first discover a possible sign of extraterrestrial life? Should we immediately take a sample for lab analysis, or study it remotely first? Some might contend that we should leave the area completely until we obtain more knowledge of that potential life-form via remote sensing and tele-robotic vehicles. Still others, as extreme and impractical as it may sound, might suggest that we leave the planet entirely, perhaps for ethical reasons,[27] or at least until more is known about the nature of that life and its distribution on the planet. How rigid will such a policy be? All these questions will, of course, be examined as they relate to Astronaut safety—which, along with the more subtle forward contamination concerns, will likely require many years of scientific research and international policy formulation before a healthy consensus can be reached. Once this Human First Detection Policy is established, then GO!

If it is thought that contamination could be global, we must try to *establish the criteria for assessing with an appropriate level of confidence the biological status of the entire planet*. This is, of course, a very tricky question—partly because we only have one data point, the earth, on which to base any criteria. However, it still may be possible to establish criteria that should be satisfied before having some appropriate level confidence about the biological status of Mars. If a few strategic missions are adequate, how many, and of what kind? If many missions are required, the same set of questions hold, with a key long-term question being the total number of missions required since this will drive the overall timetable for getting humans to Mars. If many missions turn out to be required, we should try to address the associated issues now to ensure that all preliminary steps are taken in an efficient manner as we plan our first presence on another planet.[28]

If only a few strategic missions are required, and precursor robotic exploration doesn’t find any signs of life, then establish Human First Detection Policy, and GO! If signs of extinct or extant life are found, that could imply that the determination that only a few strategic missions would be adequate to assess the biological status of Mars should be called into question, suggesting that many robotic precursor missions may be needed to assess the biological status of Mars. If many missions appear to be required, assess how many and of what kind. If no life is found, establish first Human First Detection Policy, then GO!

If life is found, try to understand what the data suggests regarding its nature. Establish and consult the Robotic First Detection Policy (presumably an international effort which should help address questions associated with what should be done prior and post a robotic detection of life. For example, what are the criteria for assessing whether humans should go immediately? What kind adverse effects are possible—mutual or otherwise?) This kind policy, which will be discussed further in a subsequent section, should be informed by research regarding possible impacts to indigenous Martian ecosystems—another key question that will be explored in more detail in the following section. If humans are needed, or if more generally, it is determined that humans should go immediately regardless, then get clear on the Human First Contact Policy, and GO!

If it is decided that humans should not go immediately, we will want to conduct extensive robotic study to understand that life, eliminating, as much as possible, the contamination effects due to many such missions. When the threshold for obtaining as much understanding as is reasonable via robotic exploration is reached, then GO!

For this decision tree, a "no-go" decision would be considered final because the decision tree allows for an extended period of time during which a no-go decision would essentially be in effect until there was enough confidence to send a human mission. Such a no-go conclusion would be extreme and would require an extremely compelling justification. Indeed, it should be noted that there may be circumstances which some would see as justification for such an absolute no-go decision. For example, it is conceivable that if Mars is teeming with a very dangerous form of life, a decision could be made to "quarantine" the planet for an indefinite period of time. However, as indicated above, the more likely scenario under such circumstances is that since humans will want to study those life forms *in situ* as we do dangerous organisms on earth, we will likely simply take whatever time and action necessary to have confidence about the first mission. There is, however, another possibility that could lead to a no-go decision. Political and ethical reasons for keeping humans away from Mars could prevail. For example, there will be those who will suggest that Mars is its own environment, its own world, that deserves to exist unaltered by human interference, especially given our propensity for facilitating undesirable environmental degradation.

3. KEY POLICY ISSUES

There appear to be at least two major areas requiring comprehensive rigorous policy analysis. One is what can be thought of as a "Robotic First Detection Policy". This policy would have something to say about what steps should be taken regarding robotic missions to minimize/ avoid compromising possible extraterrestrial life before and after possible signs of life are discovered by a robotic vehicle. The second can be thought of as a "Human First Detection Policy" which would be concerned with pre and post-detection issues involving a human *in situ* search for and discovery of Martian life. The former is not intended to be the focus of this paper, although some brief thoughts will be offered since robotic exploration issues relate to human exploration.

An analog for the policy work being suggested here exists in the Search for Extraterrestrial Intelligence, or SETI, community. There exists a Declaration of Principles Concerning Activities Following the Detection of Extraterrestrial Intelligence which provides guidelines regarding how organizations should react in response to evidence of a detection. Although such a possibility may be legitimately perceived by many to be remote, it is nonetheless, wise to be prepared for such a possibility. The same should apply to what may be a more likely possibility of discovering primitive forms of extraterrestrial life.[29] Policy should be driven not only the likelihood of an event, but its significance, as well.

Pursuit of the policy and science considered in this paper could also help in choosing among different policy directions raised by Bruce Murray who has suggested three kinds of objectives that need to be decided regarding Mars exploration: (1) Open-ended exploration leading to human mission vs. accomplishing focused scientific objectives. (2) Priority for early detection of decisive evidence of life, past or present, vs. determination of key unifying global processes. (3) Technological evolution for long range exploration vs. expedient approach to near-term objectives.[30] Although by no means definitive, the concerns raised in this paper can help make choices from Murray's list by considering life-detection as the centerpiece for Mars exploration, hence suggesting we might choose the following: (1) accomplishing focused scientific objectives, (2) early detection of decisive evidence of life, and (3) expedient approach to near-term objectives.

Also, addressing these questions now will not be wasted if we were to indeed find a lifeless Mars. This kind of planning can only help prepare us as we move out into the rest of the solar system in search of life.

3.1 Robotic First Detection Policy

3.1.1 Pre-detection

Pre-detection planning regarding robotic missions has been addressed broadly in the form of the 1967 Outer Space Treaty and more specifically in the form of contamination prevention measures implemented by space faring nations. However, the absence of rigorous international enforcement mechanisms may have allowed unacceptable contamination to occur in the past and may allow it to continue in the future. As more nations become space-faring, effective international mechanisms for enforcing contamination regulations might be necessary. Also, the new NASA policy doesn't require sterilization unless there are life-detection experiments involved. Cleaning is certainly required, but it is unclear whether this is adequate, especially when we consider the accumulation of many robotic precursor missions. Contamination could be more of a concern after a large number of missions are launched.[31]

This policy work may also include exploring guidelines regarding how robotic vehicles could best operate so as to reduce possible adverse affects on indigenous ecosystems. For example, some form of remote surveillance (either from orbit or from other vehicles/stations on the ground) of a potentially life-bearing environment may be prudent before sending rovers to the specific locale in question. This might be particularly relevant if rovers have not been adequately sterilized, which, as suggested above, the present policy could allow for if life-detection experiments were not involved.

3.1.2 Post-detection

A discovery of indigenous life by a robotic vehicle may not present any severe difficulties if we take the proper contamination precautions, and if we are willing to take the time needed after the discovery to make policy decisions about how to proceed—which will be driven largely by the circumstances. However, it may be prudent to consider some of these robotic post-detection issues now in order to prepare ourselves to whatever extent is appropriate.

For example, upon the discovery of the first sign of life, should a robotic vehicle leave the immediate locale for remote study so as to minimize impacts to that environment? Will it depend on the kind of vehicle that makes the detection? Will we opt for an immediate sample return of those life forms? Perhaps we will want to send humans immediately to the site which has evidence of extant life? Or perhaps we should take a very conservative approach and study that life via robotic explorers for an extended period of time so as to not disturb the immediate discovery site. If we choose robotic exploration, will it be of a remote nature, say from a low orbit or nearby moon, or will we land one or many vehicles at the immediate site as soon as possible?

These are not easy questions, especially considering the amount of speculation that's involved. However, it is no different, in principle, than what goes on with most contingency planning—something NASA knows how to do.

3.2 Human First Detection Policy

Although it may be prudent to address the above questions now to whatever extent we are able, we are likely to at least have time to do so after a robotic discovery is made. We may not have that luxury if *in situ* humans make the first discovery. Significant contamination leakage is likely. There will be momentum, political and otherwise, much of which is emerging now, which could be hard to curtail, especially once humans are there. Most importantly, with humans on the scene, it will be prudent to at least establish in advance some decision making mechanisms, presumably of an international nature, to deal with post-detection activities. Preferably, an international forum should establish in advance at least general, if not specific, guidelines for pre and post-detection protocols and follow-on activities.

This policy, in addition to addressing direct detection scenarios and associated issues, can, and perhaps should, be broadened to include an assessment of the overall kind of approach we will take in preparing a human mission to Mars. Here, we might capture the general issue of whether we should or will take a conservative overall planning approach with respect to the preservation of potential extraterrestrial life.

3.2.1 Pre-detection

Guidelines should be established for activities that could jeopardize indigenous ecosystems while humans are present. Contamination measures are a part of this, but there are also issues such as establishing surveillance procedures before entering an area, guidelines for movement in an area, procedures for digging and drilling, procedures for releasing waste and dealing with rocket exhaust, etc. Such guidelines for pre-detection activities of human activity may help preserve key environments where life could exist, undetected. Emphasizing minimally intrusive procedures may be one such guideline. If we are prepared to send humans, and we are not confident about possible contamination effects, perhaps we might want to define a restricted area that human activity would be confined to, especially if we think contamination effects could be global. This is also related to our understanding of how movement will affect the spread of contamination. We may also wish to consider various forms of search/detection protocols to guide astronauts' activities as they relate specifically to the search for life on Mars. Criteria for determining that any given locale is devoid of life might also be useful to help have confidence regarding the relaxation of procedures for activities in that area.

As indicated previously, construed broadly, human pre-detection policy issues can address whether or not the issues on the mission planning decision tree, taken individually and collectively, are worthy of rigorous pursuit. How important is the preservation of extraterrestrial life? How much confidence do we want to have regarding the biological status of any given locale or of the entire planet before possibly jeopardizing indigenous ecosystems with a potentially intrusive human mission? Even if we think we should and can exercise rigorous contamination controls for a human presence, *will* we? It may be that many could agree a conservative approach is warranted and even feasible, but that may not be enough for it to be realized since many forces could conspire to relax such a cautious exploratory approach. If we have some sense for this ahead of time, perhaps we will want to consider planning for many robotic precursor missions to obtain a significant degree of confidence that Mars is dead before going with the first human mission.[32]

3.2.2 Post-detection

If and when human explorers first discover life on Mars, should the astronauts leave the immediate site and do remote analysis before disturbing the site and possibly the life form any further? Or should an astronaut take a sample immediately? If so, should the sample be sterilized immediately? Will we require a quarantine facility on the surface to study possible life forms, or will it be safer to send a sample to an orbiting laboratory so as to contain any possible adverse effects? More generally, will we be prepared, technically and politically, to deal with such a discovery *in situ*? For the first mission, it may not be feasible to send and build the appropriate technology and facilities to cope with discovering extraterrestrial life. As extreme as it may sound, some might suggest that we should leave the planet entirely until we are more certain about possible mutual effects. Some may go further and suggest we leave and never return so that life can be allowed to evolve and flourish without human interference.

But we humans will not likely be able to resist the temptation of studying such a discovery. We will send more missions and probably establish a robust scientific outpost to study the new life form. Might this eventually lead to a small community as we become more efficient at utilizing the Martian resources? Should potential population growth, either by immigration or reproduction, be controlled so as to avoid jeopardizing the indigenous biota of Mars?

Clearly these are difficult questions—partly because we have so little relevant data, and partly because they are very long-term issues. Nevertheless, as mentioned previously, exploring these issues now as part of long term contingency planning is probably wise since there is time to collect the relevant data and seek a healthy international consensus.

The nature of the life that is discovered will clearly be of critical importance in exploring these issues. A bit more specifically, whether Martian life is found to have had its own separate origin (and hence very likely different from terrestrial life) will probably be very important regarding the degree of value we place in that life. If, on the other hand, it is found to belong to the same phylogenetic tree as terrestrial life (the panspermia hypothesis) then we might be less conservative—although some will argue the scientific (and perhaps ethical) merit of allowing autonomous evolution to occur in quite different environment form that on earth.

As an example, peaceful co-existence is one long-term option to consider as a thought experiment. Ironically, Richard Taylor's slogan, "Move over microbe!" might apply.[33] That is, extraterrestrial microbes might be displaced, as often happens on earth, but they need not be harmed or destroyed. Can we co-exist with Martian life?[34] Would we combine into one ecosystem? Assuming we were careful, Martian life might not be destroyed. It could, however, change via the forces of its new ecosystem. Or perhaps we will decide to preserve that life in a kind of isolated conservatory with the indigenous Martian environment intact, so that, to some approximation, it will be allowed to evolve as it might have otherwise.[35] This could satisfy many people (although there will certainly be legitimate skepticism.) This may even satisfy those who believe that primitive extraterrestrial life should evolve autonomously. The caveat, of course, would be to exercise extreme caution in our interaction with that environment.

For those who would suggest that Martian life has "rights", this compromise might not be satisfactory. Only a non-interference policy would be acceptable.[36] However, we might consider Chris McKay's compelling view that the rights of Martian life "confer upon us the obligation to assist it in obtaining global diversity and stability."[37]

Clearly, as hinted at above, underlying many of these questions are issues of value, and policy will ultimately be driven by which values are made the priority and why.

3.3 Some Relevant Value Theory

Regarding the value dimension of this issue most generally, we want to ask: How much do we value the preservation of a primitive extraterrestrial life form and why?

There is much to be said in a rigorous treatment of such a question given the great body of work that exists on ethics and values. But there have been a few recent thinkers who have addressed some ethical issues associated with space exploration and their views will be represented in this section, along with brief discussion of the applicability of some general value theories. Much of the following comes from a previous work entitled, "Do We Need A Cosmocentric Ethic?".[38]

3.3.1 Scientific Value

Certainly there is instrumental value, or more specifically, scientific value associated with the preservation of extraterrestrial life. Clearly, masking the existence of such life and/or destroying it beyond recognition would be a scientific loss of immense proportion. Biology is desperate for a second data point. And as this paper indicates, there are many important questions that need consideration if we are to ensure the benefits associated with this scientific value. However, it isn't clear that scientific value will be enough to warrant the kind of conservative approach that may be needed to ensure the preservation of possible indigenous extraterrestrial life, thereby realizing that scientific value. As history has painfully demonstrated, the momentum of doing a thing, of accomplishing a goal to satisfy certain needs or desires, often overshadows contemplation of consequences and any potential policy action that might result thereof. The exploration and exploitation of the Americas, while certainly having some positive effects, is a poignant example of the harm we are capable of when we do not take pause to consider the consequences of our actions. Also, looking further ahead, we might also wish to consider how we will guide our actions when the scientific novelty wears off.

3.3.2 Anthropocentrism

Generally, anthropocentrists would not have much reservation about displacing or possibly destroying indigenous extraterrestrial life if it was required for human exploration and colonization of an extraterrestrial environment. Anthropocentric ethical views make humans needs and desires the priority, generally at the expense of all else.

As Robert Zubrin points out, an obvious problem for those who would answer no to whether human settlement of Mars should take priority over the continued existence of extraterrestrial microbes is to provide some explanation as to why such an answer wouldn't apply to terrestrial microbes which we wouldn't hesitate to kill with an antibiotic pill.[39] This is a reasonable challenge. However, at the same time, it also seems reasonable to suppose that extraterrestrial microbes should not be viewed the same as terrestrial microbes. Zubrin himself acknowledges their unique value.[40] An answer to Zubrin's challenge might be to point out that extraterrestrial microbes are not likely to be pro-actively destructive to our well-being, as are terrestrial microbes. Perhaps extraterrestrial microbes should be assumed innocent until proven otherwise. Also, perhaps more importantly, assuming Martian microbes are not of the same phylogenetic tree as life on earth, as a species, they would be unique in a way that terrestrial microbes are not. This significant uniqueness might imply some kind or degree of value, instrumental or otherwise, that might not necessarily be attributed to terrestrial microbes.[41]

Criticisms of anthropocentrism that it fails to consider ecological concerns and long-term effects are not so obvious since one can be concerned about the long-term ecological impacts on humans.[42] However, it has generally been the case that anthropocentrism has been more short-sighted than far-sighted. These complaints reflect a deeper instinct articulated by the philosopher Don MacNiven that theories biased towards humans are suspect.[43] This concern is supported by thousands of years of seeing our knowledge expand, constantly de-centralizing human beings—"The Great Demotions," as Ann Druyan has poignantly observed. It may ultimately be true, if we can even know such a thing, that anthropocentric value theories are valid, but we would be wise to heed the lessons of history and consider broader views.

3.3.3 Utilitarianism

A traditional utilitarian view has at its heart the concept of intrinsic value in the form of pleasure. Such a view, while used to justify respectful treatment of animals because they experience pleasure and pain, does not seem applicable to extraterrestrial microbes. We might consider, then, that the anthropocentric bias noted by MacNiven, although diluted by an expanded sphere of moral considerability in some utilitarian views, could still hold against a view that excludes primitive life forms that do not feel pain. Indeed, objective justification for the intrinsic value of pleasure requires much elucidation. In addition, appealing to happiness or pleasure as a variable for measuring value seems ultimately to involve much subjectivity, retaining a fundamental dilemma of assessing and/or measuring value.

3.3.4 A Geocentric Bias?

Robert Haynes, Chris McKay, and Don MacNiven have been prompted by the consideration of extraterrestrial activities to suggest the need for a "cosmocentric ethic". They conclude that existing ethical theories exclude the extraterrestrial environment because they are geocentric and cannot be applied to extraterrestrial environments, hence leaving a vacuum for a cosmocentric ethic.[44] Haynes says that anthropocentrism implies geocentrism because we know of no other sentient beings in the Universe.[45] Perhaps in some sense this is true for now because we only inhabit the earth, but can't we take our anthropocentrism with us anywhere we go? And can't we still be anthropocentrists if we were to discover extraterrestrial intelligence? Haynes' claim doesn't seem to apply in a general sense. McKay notes that ecological ethics has been "inextricably intertwined" with life on earth and so he comes to the same conclusion.[46] But this observation does not necessarily rule out the application of existing ethical theories to extraterrestrial considerations. If a theory excludes entities from moral consideration, it could very well be because the theory requires it, not necessarily because it's geocentric, or because it hasn't been applied to extraterrestrial considerations (although certainly these thinkers are right to question the applicability of existing views that do not address extraterrestrial considerations since such an omission might indeed be evidence of an incomplete theory.) MacNiven, while offering no additional reasons, agrees with Haynes and McKay, and further suggests that anthropocentrism, zoocentrism, and biocentrism would present no moral objection to activities such as terraforming.[47]

There may be, however, a deeper instinct being expressed by these thinkers that is more akin to realizing deficiencies in existing ethical views in general, not just as they apply to issues of space exploration—although it may be that the new context, or lens of space exploration, has rightly prompted the consideration of a new perspective—i.e. a cosmocentric perspective.[48] Nevertheless, some traditional ethical ideas have been applied to the issues at hand.

3.3.5 Rights, Intrinsic Value, and Bio/Ecocentrism

Carl Sagan's sentiment, noted in a previous footnote, is worth repeating: "If there is life on Mars, I believe we should do nothing with Mars. Mars then belongs to the Martians, even if they are only microbes."[49] Although the notion of rights is not directly invoked in Sagan's remark, his kind of view can be associated with such a rights based ideology. Similarly, Chris McKay's view is based on the intrinsic value of life principle and hence suggests that Martian microbes have a right to life—"to continue their existence even if their extinction would benefit the biota of Earth."[50] Haynes suggests that Tom Regan's arguments in his 1982, *All That Dwell Therein*, would ascribe "direct moral significance" to indigenous exoecosystems[51] (and hence presumably the resident microbes).

Such "rights" based views need to demonstrate why life should be considered intrinsically valuable and why microbes would have an absolute right to life. Rights are problematic because they are often seen as matters of degrees when difficult decisions have to be made. Degrees of rights, in the final analysis, ultimately seem no different than degrees of value. Indeed, J. Baird Callicott writes: "The assertion of 'species rights' upon analysis appears to be the modern way to express what philosophers call 'intrinsic value' on behalf of nonhuman species. Thus the question, 'Do nonhumans species have a right to exist?' transposes to the question, 'Do nonhuman species have intrinsic value?'"[52] If one claims that other animals have rights and that there are no degrees of rights, how are we to assess those situations that involve conflict of rights and/or interests between humans and other life forms?[53]

Robin Attfield, and Paul Taylor each take similar approaches to justifying the intrinsic value of life. As beings with "natural fulfillments" or "goods of their own", organisms are "teleological centers of life" in that they are motivated by the goal of maintaining their existence. With such a good of their own, living organisms are thought to have intrinsic value, all in the same degree.[54]

Donald VanDeVeer explores, within the context of environmental ethics, possibilities involving *degrees* of value and rights. He writes that he is not aware of any plausible analysis of inherent or intrinsic value such that those very concepts preclude judgements of varying levels of value. His is a biocentric, stepped egalitarianism view roughly categorizing life into three broad groups: being alive, being sentient, and possessing rational autonomy. He cites some support from our intuitions regarding differential judgments and treatment and acknowledges the subtle complexities involved in assessing degrees of value.[55]

Freya Mathews, in *The Ecological Self* (1991), suggests degrees of intrinsic value might be associated with degrees of complexity when considering the worth of an individual. The greater the complexity, the greater the power and degree of self-maintenance, where self-realization is a fundamental element of intrinsic value. However, Mathews also goes on to articulate a view in which intrinsic value is thought to shift and flow in a systemic context, resulting in an "averaging" of intrinsic value throughout the whole.

3.3.6 A Hybrid View

Steve Gillett has suggested a hybrid view combining anthropocentrism as applied to terrestrial activity combined with biocentrism towards worlds with indigenous life.56 Invoking such a patchwork of theories to help deal with different domains and circumstances could be considered acceptable, and perhaps even desirable, especially when dealing with something as varied and complex as ethics. Indeed, it has a practical common sense appeal. Andrew Brennan is critical of moral theory that attempts to encompass the complexity of life under a single principle and hence embraces a pluralistic approach to environmental ethics.[57] Alan Marshall writes of a "postmodern associationism" which, based on the deconstruction of metaphysical unity, "places an emphasis on respecting the other as arbiter of its own reality, without imposing metaphysical imperialism under the guise of a great organic unity," perhaps leading to an "appreciation of ontological meaninglessness, disunity, difference and respect for individuals as *others*—rather than as colonies of unity…"[58] We might also consider another view of this legitimate epistemological issue. Callicott writes: "But there is both a rational philosophical demand and a human psychological need for a self-consistent and all-embracing moral theory. We are neither good philosophers nor whole persons if for one purpose we adopt utilitarianism, another deontology, a third animal liberation, a fourth the land ethic, and so on. Such ethical eclecticism is not only rationally intolerable, it is morally suspect as it invites the suspicion of ad hoc rationalizations for merely expedient or self-serving actions."[59]

3.3.7 Anthropogenic Intrinsic Value

For Callicott, species possess a "truncated" version of the traditional definition of intrinsic value in that they have value "for" themselves, for their own sake, but not "in" themselves, independent of a valuing consciousness.[60] The basis for Callicott's perspective on intrinsic value is a Human/Darwinian emotive/bioempathic view which suggests that emotionally based value identification with other living things results from natural selection. Furthermore, relativism can be avoided by appealing to Hume's "consensus of feeling" which standardizes or fixes the human psychological profile and values that result thereof. Although value may not be focused solely on humans in this view, humans are indeed the source of value (i.e. value is *anthropogenic*) in that we recognize intrinsic value of other living things as their "standard" genetic make-up dictates. But is such recognition of the intrinsic value of nonhumans so standard or fixed? It appears not since there exists much intense, often violent, controversy over the value of nonhumans. Hence, there still appears to be an inherent subjectivity on an individual as well as a collective basis, since the feelings of humans are what generates the intrinsic value (making the invocation of the word 'intrinsic' somewhat suspect). This view, then, seems not to objectively justify intrinsic value or provide a way for measuring such value when difficult decisions have to be made.

3.3.8 Organic Unity

Robert Nozick draws from aesthetics the concept of organic unity in which to ground intrinsic value. He says: "The more diverse the material that gets unified (to a certain degree), the greater the value."[61] This unity in diversity is what Nozick suggests can be equated with intrinsic value. More precisely, he suggests that it might be the best *approximation* to value because our experience may be limited regarding what is valuable.[62] However, although Nozick gives a compelling account of how organic unity fits with our general perception of value, ultimately, what appears to be missing is a truly objective justification for why organic unity should be considered intrinsically valuable.[63]

3.3.9 Cosmocentrism

We have seen that various thinkers suggest the need for a cosmocentric ethic. Robert Haynes writes:

> These considerations suggest to me that we need from philosophers a new "cosmocentric" ethics, and perhaps a revised theory of intrinsic worth, if we are to evaluate the moral pros and cons of proposals for ecopoiesis (small-scale ecosystem construction) in an intelligent and sensitive way. As I see it, the first objective of such an ethic would be to resolve the dialectical contradiction that commonly arises between superficial views of "evolutionary progress" and "ecological harmony." If pushed to their obvious extremes these conflicting myths could lead the grossest kind of human environmental imperialism on the one hand, or to the destructive elimination of all technology, including modern medicine and agriculture, on the other. For me, a cosmocentric ethic would allow scope for human creativity in science and engineering throughout the solar system, but also recognize that at present we depend utterly on the vitality of the Earth's biosphere for our very existence. It would recognize also that the physical artifacts of humanity are as much a part of the Universe as are stars, planets, plants and animals.[64]

Although by no means well-defined, a cosmocentric ethic might be characterized as one which (1) places the Universe at the center, or establishes the Universe as the priority in a value system, (2) appeals to something characteristic of the Universe (physical and/or metaphysical) which might then (3) provide a justification of value (presumably intrinsic value), and (4) allow for reasonably objective measurement of value. Related to this kind of ethic are views which appeal to "cosmologies" as the foundation for ethical views.[65]

At first glance, talk of a cosmocentric ethic might seem paradoxical. How can an ethical view be centered or focused on “all that is”? From egocentrism to eco/geocentrism, we are able to center, focus, and prioritize value because there is some other, generally larger frame of reference which is relatively de-valued. Nevertheless, as has been suggested by others noted above, such an ethic may be helpful in dealing with value based questions involving extraterrestrial issues such as interaction with indigenous primitive extraterrestrial life forms.

As with environmental ethics, the central issue for a cosmocentric value theory is justifying intrinsic value.[66] Indeed, the significance of appealing to the Universe as a basis for an ethical view is that an objective justification of intrinsic value might be realized to the greatest extent possible by basing it on the most compelling objective absolute we know—the Universe. In a pantheistic world-view, this is functionally equivalent to knowing the nature of, and perhaps doing the “will” of, God. In addition, we should like to have some way of objectively assessing, preferably measuring, value.

3.3.9.1 The Projective Universe’s Formed Integrity

Holmes Rolston proffers a compelling view which appeals to the “formed integrity” of a “projective Universe.” This view suggests that the Universe creates objects of formed integrity (e.g. objects worthy of a proper name) which have intrinsic value and which should be respected.[67] However, Haynes points out that Rolston’s view appears to conflict with modifying the earth, even to the benefit of humans.[68] Rolston’s view would certainly call for the preservation of primitive extraterrestrial life.

In Rolston’s view, justification of intrinsic value might come from the creative processes of the Universe itself—that is, the creative process, and all that results from it, is intrinsic to the Universe.[69] However, in assigning value to the Universe’s creative processes, we might be guilty of anthropomorphizing the Universe.[70] Indeed, we could ask why the Universe is a creative entity—which might shed light on the general requirement for more rigorous elucidation of how the Universe’s creative process can give rise to a justification for intrinsic value.

Rolston’s view also attempts to address the problem of assessing or measuring value by suggesting that if a thing has formed integrity, or is worthy of a proper name, it should be respected, which presumably means left alone. But how do we decide what has formed integrity so that it will be named? This is the value measurement problem in a different form. Conflict ultimately remains since personal subjective value judgments seem unavoidable in assessing what has formed integrity.

3.3.9.2 The Sanctity of Existence

MacNiven has suggested that a central tenet of a cosmocentric ethic would be the principle of the sanctity of existence, which, he notes, would make it difficult to justify the significant modification or destruction of indigenous life forms.[71] In a minimal sense, the principle of the sanctity of existence might satisfy criterion one and two for the definition of a cosmocentric ethic suggested previously because the Universe, and all therein, exists. However, we do not see a compelling articulation of why, specifically, all things have intrinsic value because they exist. We should prefer some justification of the principle itself as well as its invocation. MacNiven additionally suggests appealing to a "selective concept of uniqueness" as we sometimes do in considering terrestrial matters such as preserving the Grand Canyon.[72] Here, again, we might ask why uniqueness should have intrinsic value. Even in light of the notion of uniqueness, the issue of measuring value—or more specifically, of weighing the value of human activity against other forms of value such as the preservation of an extraterrestrial life form still appears to be without a firm theoretical foundation.

3.3.9.3 Connectedness

The systemic, interdependent connectedness of ecosystems is often cited as a foundation justifying the value of parts of the larger whole, since a subset contributes to the maintenance of the larger whole. Consider Leopold's egalitarian ecosystem ethic: "A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong if it tends to do otherwise."[73]

In *The Ecological Self*, Freya Mathews suggests that intrinsic value can be grounded in self-realization, which is a function of interconnectedness. The Universe qualifies for self-hood and hence self-realization (again, for which interconnectedness plays a critical role) and humans participate in this cosmic self-realization.[74]

Construed cosmically, then, connectedness may hold promise for a cosmocentric ethic. In particular, it may be that connectedness itself is a *necessary* property of the Universe, and that to actualize/instantiate a connection *necessarily* requires an interaction—hence connectedness gives rise to, or is instantiated via, interaction. Such a view might favor maximizing interaction and any other consequence of realizing robust actualizations of connectedness/interaction action (perhaps, for example, complexity, creativity, uniqueness, diversity, intensity, etc.) as the foundation of a cosmocentric ethic since it would contribute to the greatest realization of the nature of the Universe (i.e. its "self-realization"). Indeed, in making choices consistent with this view, humans might help propagate diversity here on earth and throughout the Universe, but not *necessarily* at the expense of other robust actualizations of connectedness (e.g. perhaps other "kinds" of life forms).[75] The trick would be to assess relative degrees of value corresponding to degrees of realizing connectedness/interaction.[76]

3.3.10 The Fact/Value Problem

It is important to acknowledge the importance of the fact/value (or "is/ought") dilemma which suggests, among other things, that knowing something about the way the Universe is cannot lead to a justification of value. Thankfully, this complex philosophical problem, although ultimately relevant, is beyond the scope of this paper. But, consider that this problem can also be understood as the idea that values do not necessarily follow from facts—not that values absolutely cannot follow from facts. That is, if we find a fact-based value theory compelling enough, we have the choice to associate and/or derive value (an "ought") from what "is".[77] Our value theories can be models just like physical theories. What's important, of course, is that they have broad explanatory and problem-solving power.

The ecologist Frank Golley has argued that activities in space such as the colonization and terraforming of Mars will be unavoidable since it is consistent with the dominant myths and metaphors of western civilization. Historically, these dominant myths and the exploration that results from them have not been concerned about the indigenous systems they effect, including the existence of human beings. Is this the kind of action that is unavoidable? Golley suggests that to turn away from these pursuits would require a fundamental reorientation of our culture.[78] If a lack of concern for indigenous systems is part of our dominant myths and exploratory pursuits, then perhaps a fundamental reorientation of our culture is exactly what's needed. Ironically perhaps, this would be consistent with Robert Zubrin's vision of Mars as an opportunity for the grand, noble experiment—a chance to realize new ways of life. Indeed, we could explore, create a new branch (or branches) of human civilization, terraform, etc.—all the while fostering and exercising a kind of respect and caution that has traditionally been absent. To some degree, it's already happening. This century's strong environmental and animal rights movements are powerful examples. We need only to continue to foster extend these concerns to extraterrestrial environments.

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Finally, some may argue that the rational pursuit of ethics is futile—that rationality is slave to the passions, and/or that economics (competition for resources) is the primary motivation for human activity. Perhaps this is partly true. But, there is certainly a critical role for considered rational thought regarding what we value and why. Human beings are extremely diverse, and are motivated by many different forces. Ultimately, through a mix of reductive, creative, and ecological thinking, as favored by Frederick Turner,[79] a compromise among many diverse forces will likely strike a reasonable balance regarding how the status of extraterrestrial life will fit into our policies for exploring our solar system and beyond.

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12.

McKay and Davis note several sources of environmental impacts due to a human base that should be considered, including mechanical disturbances, life support system leakage, airborne pollution, and "seemingly innocuous perturbations" like water, heat, light, etc. P. 198.

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For an analysis of social factors see: Margaret S. Race, Societal Issues as Mars Missions Impediments: Planetary Protection and Contamination Concerns. *Advanced Space Research* Vol. 15, p. 285 (1994).

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H. P. Klein, *Planetary Protection Issues for the MESUR Mission: Probability of Growth (Pg)*. NASA Conference publication. NASA Ames Research Center, Moffett Field, California, (1991).

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16.

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17.

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Freeman Dyson brought this terrestrial analog to my attention in a personal conversation (Aug. 1998).

20.

Indeed, many personal conversations with average laypersons, scientists, and senior NASA managers bear this out.

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J. C. Sharp, Manned Mars Missions and Planetary Quarantine Considerations, *Manned Mars Missions*, NASA M002, NASA Washington, D.C., p. 553, (June 1986).

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25.

McKay and Davis, p. 198.

26.

McKay and Davis, p. 198.

27.

Carl Sagan has written: “If there is life on Mars, I believe we should do nothing with Mars. Mars then belongs to the Martians, even if they are only microbes.” Carl Sagan, *Cosmos*. Random House, New York, p. 130 (1980). It’s not clear if this implies we stay off the surface completely, use sterilized robots only, or just prohibit colonization while allowing *in situ* experimentation via human explorers.

28.

It should be mentioned that it will obviously be important to consider the scenario that contamination will be regional—that is, somewhere in between local and global. This will reduce the global biological status problem somewhat, but the fundamental challenges remain, including assessing the type, extent, and geographical range of contamination number and kind of missions that might be required.

29.

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30.

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31.

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33.

Martyn Fogg notes a radio interview with Richard Taylor. Martyn Fogg, *Terraforming: Engineering Planetary Environments*. SAE International, Warrendale, p. 494 (1995).

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Mark Lupisella and John Logsdon, "Do We Need A Cosmocentric Ethic?" Paper IAA-97-IAA.9.2.09 presented at the 48th Congress of the International Astronautical Federation, Turin, Italy (October 1997).

39.

Zubrin, The Terraforming Debate, pp. 3-4.

40.

Zubrin and Wagner, *The Case For Mars*, p. 135.

41.

Indeed, we will see that Don MacNiven and others cite the importance of uniqueness in determining value.

42.

Indeed, many environmentalists are also anthropocentrists. Eugene Hargrove, in *Foundations of Environmental Ethics*, Prentice Hall, (1989), considers aesthetics as an anthropocentric foundation of environmental ethics. In *Why Preserve Natural Variety?* (1987), Bryan Norton advocates the "transformative" value (e.g. the effect of positively enhancing, ennobling, etc.) that other species have on humans. J. Baird Callicott, in *Moral Considerability and Extraterrestrial Life* (p. 252) applies Norton's "weak anthropocentrism" to the issue of preserving primitive extraterrestrial life by appealing to its transforming and ennobling effect on human nature. He says, "I can think of nothing so positively transforming of human consciousness as the discovery, study, and conservation of life somewhere off the earth." Witness also the poignant poster of the Earth under which reads, "Save The Humans."

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Haynes, Playing God On Mars, p. 176.

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McKay, Does Mars Have Rights? p. 196.

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Donald MacNiven, Environmental Ethics and Planetary Engineering. *Journal of the British Interplanetary Society* Vol. 48, pp. 442-443 (1995). Also published as Paper AAS 97-389 in *From Imagination to Reality: Mars Exploration Studies of the Journal of the British Interplanetary Society* (Part II: Base Building, Colonization and Terraformation), R. M. Zubrin, ed., AAS *Science and Technology Series*, Vol. 92, pp. 303-307 (1997).

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Carl Sagan, *Cosmos*. Random House, New York, p. 130 (1980).

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McKay, Does Mars Have Rights? p. 194.

51.

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53.

Deep Ecology views tend to have as a central tenet, biological egalitarianism, according to which all organisms have an equal right to life. See Arne Naess, *Ecology, Community, and Lifestyle: Outline of an Ecosophy*, Cambridge, 1989.

54.

Wayne Ouderkirk, Earthly Thoughts: An Essay on Environmental Philosophy, *Choice*, November 1997, p. 424. Robin Attfield, *The Ethics of Environmental Concern*, 2nd ed. Georgia Press (1991). Paul Taylor, *Respect for Nature: A Theory of Environmental Ethics*, Princeton (1989). Also, Bernard Rollin draws a line between protozoa which exhibit behavior that might indicate consciousness (albeit broadly defined) and bacteria and plants for which there is no such evidence. *Animal Rights and Human Morality*. Prometheus Books, Buffalo, pp. 39-42 (1981). Carl Sagan seems to articulate an even more general view when he says: "Consciousness has various meanings. If it means an awareness of the external world, and modifying your behavior to take account of the external world, then I think microbes are conscious." Carl Sagan, "The Age of Exploration", in *Carl Sagan's Universe*, ed. Y. Terzian and E. Bilson, p. 154 (1997).

55.

Donald VanDeVeer, Interspecific Justice and Intrinsic Value, *The Electronic Journal of Analytic Philosophy*, 3, Spring 1995.

56.

Steve Gillett, The Ethics of Terraforming, *Amazing*, pp. 72-74 (August 1992).

57.

Andrew Brennan, *Thinking About Nature: An Investigation of Nature, Value, and Ecology*, (1988).

58.

Alan Marshall, A Postmodern Natural History of the World: Eviscerating the GUTs from Ecology and Environmentalism, *Studies in History and Philosophy of Biological and Biomedical Sciences*, p. 158, 160 (1998).

59.

Callicott, Moral Considerability and Extraterrestrial Life, p. 251.

60.

Callicott, On the Intrinsic Value of Nonhuman Species, p. 143.

61.

Robert Nozick, *Philosophical Explanations*, Cambridge: Harvard University Press, p. 416 (1981).

62.

Nozick (1981), p. 442.

63.

Diversity is found to be an important tenet in many world-views, especially environmentally sensitive world-views. Freeman Dyson writes: “Diversity is the great gift which life has brought to our planet and may one day bring to the rest of the Universe. The preservation and fostering of diversity is the great goal which I would like to see embodied in our ethical principles and in our political actions.” *Infinite In All Directions*. New York: Harper & Row, (1988). Peter Miller offers the notion of “richness” (which can be roughly equated with diversity) as a “generalized normative concept” against which to assess value. Value as Richness, *Environmental Ethics*, vol. 4, no. 2, p. 106-107, (Summer 1982). Richard Hanley, in *The Metaphysics of Star Trek*, Harper Collins, 1997, p. 17, calls attention to the “well-known Vulcan IDIC credo (‘Infinite Diversity in Infinite Combinations’). In *The Ecological Self* Barnes & Noble (1991), Freya Mathews argues along Leibnizian/Spinozian lines that “the actual world, must be the *fullest* possible world.” In its barest form, this is Arthur Lovejoy’s principle of plenitude (*The Great Chain of Being*, 1971), versions of which have been proposed since Plato’s Demiurge (a “God” who “wanted the world to lack nothing”).

64.

Haynes, Ecopoiesis: Playing God On Mars, p. 177.

65.

See, for example, the critical role of cosmology in Freya Mathews’, *The Ecological Self* (1991), Arran Gare’s *Postmodernism and the Environmental Crisis* (1995) for a criticism of postmodernism as an “inadequate guide for political action or how to live”, suggesting the need for a kind of “postmodern cosmology”, and Joseph Grange’s, *Nature: An Environmental Cosmology* (1997). Carolyn Merchant, in *Radical Ecology: The Search for a Livable World* (1992) stresses that ecological ethics is a radically different form of ethics grounded in the cosmos.

66.

Callicott writes: “In addition to human beings, does nature (or some of nature’s parts) have intrinsic value? That is the central theoretical question in environmental ethics. Indeed, how to discover intrinsic value in nature is the defining problem for environmental ethics. For if no intrinsic value can be attributed to nature, then environmental ethics is nothing distinct. If nature, that is, lacks intrinsic value, then environmental ethics is but a particular application of human-to-human ethics. Or, putting the same point yet another way, if nature lacks intrinsic value, the nonanthropocentric environmental ethics is ruled out.” Intrinsic Value in Nature, *The Electronic Journal of Analytic Philosophy*, 3, Spring 1995.

67.

Holmes Rolston III, The Preservation of Natural Value in the Solar System, E. C. Hargrove (Ed.), *Beyond Spaceship Earth: Environmental Ethics and the Solar System*, Sierra Club Books, San Francisco, (1990).

68.

Haynes, Playing God on Mars, p. 177.

69.

Similar to MacNiven's view, this perspective has been referred to as "object-centered" by Richard Miller, in an independent study entitled, "The Greening of Mars: Ethics, Environment, and Society, Terraforming: An Ethical Perspective." University of Waterloo, Canada, (1996). Rolston also articulates a more specific view regarding the intrinsic value of primitive organisms whereby "A life is defended for what it is in itself, without further contributory reference…That is ipso facto value in both the biological and philosophical sense, intrinsic because it inheres in, has focus within, the organism itself." *Conserving Natural Value*, Columbia University Press, p. 173 (1994).

70.

Generally, this anthropomorphizing tendency causes suspicion regarding a view's validity. However it could, ironically, be interpreted as evidence to support or justify intrinsic value—perhaps via some version or derivation of the Anthropic Principle, for example.

71.

MacNiven, Environmental Ethics and Planetary Engineering, pp. 442-443 (1995).

72.

MacNiven, pp. 442-443.

73.

Aldo Leopold, *A Sand County Almanac*, New York, p. 262, (1966).

74.

Mathews articulates self-hood and self-realization, generally, and in a cosmic sense, in Chapter 3, and the associated ethical implications in Chapter 4.

75.

Indeed, the kind of life that might exist on Mars could play a critical role in what kind of value is assigned to it. The cosmocentric view suggested here might imply that a unique extraterrestrial life-form be assigned a higher value than primitive terrestrial organisms, since it would constitute a significantly different universal creation (where creation of new, robust forms of interaction are a central—perhaps intrinsic—value suggested by the cosmocentric ethic.)

76.

In, From Biophysical Cosmology to Cosmocentrism, (*SETI In The 21st Century: Cultural and Scientific Aspects*, SETI Australia Centre, January 1998), I try to articulate the philosophical principles and implications of such a view.

77.

Callicott claims that Hume's is/ought dichotomy can be bridged "in Hume's terms, meeting his own criteria for sound practical argument." Hume's Is/Ought Dichotomy and the Relation of Ecology to Leopold's Land Ethic, *Environmental Ethics*, Vol. 4, (Summer 1982).

78.

F. B. Golley, "Environmental Ethics and Extraterrestrial Ecosystems," *Beyond Spaceship Earth: Environmental Ethics and the Solar System*, ed. E. C. Hargrove, San Francisco, Sierra Club Books, p. 225 (1986).

79.

Frederick Turner, Life On Mars: Cultivating a Planet and Ourselves, Harper's Magazine (August 1989).

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restrial and martian biospheres â€˜â€˜if Earth life and martian. life are related, or if martian life is unrelated but still uses. DNA/RNA.â€™â€™ This is in blatant contradiction to their preÂ after the possible detection of fossilized life on Mars (McKay. et al., 1996); (iii) the initiative that the Chairs of the Mars. Habitability Session at the 2010 Astrobiology Science ConÂ If a Martian mission leads to the discovery of microbial life, how would one know if this is Martian or hitchhikers from Earth? Earth's Stratosphere and Microbial Life. Article. Possible. landing site. MARS.Â A drill will extract samples from Martian rocks. The Sherloc device will identify molecules and minerals to detect potential biosignatures, with help from the Watson camera. PiXI will identify chemical elements to seek signs of past life on Mars.Â Tests of these tools on Earth demonstrated the possibilities of finding preserved signs of past life. The mission will also collect a series of rock and dirt samples to be picked up by a future mission to Mars and eventually brought back to Earth. â€" Kenneth Chang. Knowing that impact glass can preserve ancient signs of life â€" and now knowing that such deposits exist on the Martian surface today â€" opens a potential new strategy in the search for ancient Martian life, the researchers say. â€œWe think these could be interesting targets for future exploration,â€ Mustard said. In fact, Mustard and Cannon have a particular spot in mind.Â â€œIf you had an impact that dug in and sampled that subsurface environment, itâ€™s possible that some of it might be preserved in a glassy component,â€ Mustard said. â€œThat makes this a pretty compelling place to go look around, and possibly return a sample.â€ Source: Brown University. Mars is known to be well endowed with most of the elemental building blocks of life, although the martian inventory of nitrogen, in particular, remains poorly understood (Mancinelli, 1996).Â Moreover, geologic processes have managed to preserve organics in terrestrial sedimentary rocks for billions of years (e.g., Foriel et al., 2004), despite oxidizing surface conditions.Â The metabolic activity of a potential martian biosphere is one of several possible explanations for recent claims of the detection of roughly 10 ppb of methane in the martian atmosphere (Mumma et al., 2004; Krasnapolsky et al., 2004; Formisano et al., 2004). If life once existed there, it likely didn't evolve beyond the single-cell stage, scientists say. That's because Jezero crater formed over 3.5 billion years ago, long before organisms on Earth became multicellular. If life once existed at the surface, its evolution was stalled by some unknown event that sterilized the planet. That means the Martian crater could serve as a kind of time capsule preserving signs of life as it might once have existed on Earth.Â The article, originally titled â€˜Promising signs for Perseverance rover in its quest for past Martian lifeâ€™ first appeared on ScienceDaily from the source: Stanford's School of Earth, Energy & Environmental Sciences, dated 23/04/2020 and has been republished with permission. References. LapÃ´tre, M. & Ielpi, A. 2020.