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Humans Should Not Colonize Mars

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ABSTRACT: This article offers two arguments for the conclusion that we should refuse, on moral grounds, to establish a human presence on the surface of Mars. The first argument appeals to a principle constraining the use of invasive or destructive techniques of scientific investigation. The second appeals to a principle governing appropriate human behavior in wilderness. These arguments are prefaced by two preliminary sections. The first preliminary section argues that authors working in space ethics have good reason to shift their focus away from theory-based arguments in favor of arguments that develop in terms of pre-theoretic beliefs. The second argues that, of the popular justifications for sending humans to Mars, only appeals to scientific curiosity can survive reflective scrutiny.

KEYWORDS: space ethics, environmental ethics, Mars colonies, philosophical methods

The timeline for the first crewed mission to Mars is now measured in years, not decades, and the near-term ambitions of real-world firms and agencies have shifted from limited duration science missions to permanent colonies. Says SpaceX CEO Elon Musk: “I think we should establish [human] life on another planet--Mars in particular.... SpaceX is intended to make that happen” (Thomas 2007). Says Sheikh Mohammed bin Rashid Al Maktoum, Emir of Dubai: the Mars 2117 project, announced by the United Arab Emirates in 2017 “integrates a vision to create a mini-city and community on Mars” (Taylor 2017). Says NASA: “There are challenges to pioneering Mars, but we know they are solvable. We are well on our way to getting there, landing there, and living there” (Wilson 2016).

Should we do this? Should humans colonize Mars?

0. Preliminary: The method appropriate to the question

The term "applied ethics" embraces at least two distinct methods of approaching practical moral controversies. Call these methods the theory-centered mode and the practical-controversy-centered mode.

Applied ethics in the practical-controversy-centered mode begins by identifying a set of widely held beliefs---about cases, about pre-theoretic principles, etc.---then argues that these beliefs entail conclusions readers might not have noticed. For example: the widely held belief that it is morally permissible to disconnect from the famous violinist in Thomson's described case entails that a right to life doesn't entail a right to life-support (Thomson 1971); the widely accepted pre-theoretic principle that we ought to take low-cost opportunities to prevent serious suffering entails that we should donate much of our income to effective poverty relief (Singer 1972).

Applied ethics in the theory-centered mode first endorses or develops a general theory---of normative ethics, of personhood, of intrinsic value, etc.---then argues that the theory, properly interpreted, answers the practical question at hand. For example: Kantian moral theory, properly interpreted, entails a duty to vegetarianism (Korsgaard 2004); Attfield's biocentric theory of intrinsic value, properly interpreted, provides non-instrumental, but not absolute, reasons for protecting trees (Attfield 1981.)

At a glance, the difference between these methods is liable to be overlooked, since both methods result in the assertion of a practical conclusion. The risk of confusion is especially acute when an author writing in the theory-centered mode introduces a *novel* theory. The process of theory construction standardly begins by identifying a set of widely held beliefs that constitute the "data" the theorist seeks to systematize, explain, and justify with a theory. In that case, theory-centered and practical-controversy-centered arguments both begin by identifying pre-theoretic beliefs, and both end with the assertion of a practical conclusion. Nevertheless, the paths these approaches take on the way to a practical conclusion are clearly distinct. Arguments in the practical-controversy-centered mode argue directly from pre-theoretic beliefs to practical conclusions. Arguments in the theory-centered mode derive practical conclusions from the interpretation of a theory.

With this distinction in hand, it is clear that much of the existing work in space ethics, including some of the best-known, is applied ethics in the theory-centered mode. Some papers apply a general moral theory to answer a space-ethics question. Sparrow (1999) applies agent-based virtue theory to generate the conclusion that terraforming Mars is morally wrong. Baum (2016) argues that currently popular varieties of consequentialism entail that we morally ought to direct resources to protecting Earth, not to colonizing other planets. McArthur and

Boran (2004) apply a Kant-friendly, agent-centered theory to generate deontic constraints on exploration.

Other papers endorse or extend existing theories of intrinsic value. Richard York (2005) argues that Leopoldian ecocentrism entails stringent protections for Mars. Cockell (2005) develops a microbe-focused version of Leopoldian ecocentrism, which holds that individual microbes have (merely) theoretical intrinsic value while microbial communities have operational intrinsic value. When applied, this theory entails a duty to preserve Mars. Paul York (2005) extends Taylor's biocentric theory of intrinsic value into a theory York calls Universal Ethics, then argues that Universal Ethics forbids terraforming.

Still other papers develop novel theories of intrinsic value. Lee (1994) grounds her theory in three core theses about nature: the no-teleology thesis, the asymmetry thesis, and the autonomy thesis. She argues that this theory of intrinsic value requires of us an attitude of awe and humility toward nature, which attitude is incompatible with terraforming Mars. Scherer (1988) argues that entities or systems that strive against entropy are intrinsically valuable, and thus space explorers have a duty to avoid endangering the disentropic enterprise wherever they go. Smith (2014) develops a theory of intrinsic value rooted in a complex of higher features he calls the "sociality-reason-culture triad," then applies this theory to yield a permissive set of norms governing our treatment of any extraterrestrial life we might discover.

Applied ethics in the theory-centered mode plays several important philosophical roles. Vigorous efforts to locate the best theoretical terms in which to discuss the problems of space ethics might well be the first phase of a process that will lead to important theoretical sorting and improvement in the future (Schwartz 2016). Work in the theory-centered mode contributes to theory construction, elaboration, and testing. And theories can, over time, come to alter the terms of practical debates.

However: applied ethics in the theory-centered mode can make little or no direct contribution to public discussion of space-ethics controversies. Consider Sparrow (1999), which argues that Slote-ian agent-based virtue theory entails that terraforming Mars is morally wrong. In order for a reader to be persuaded that Sparrow has provided a genuine reason not to terraform, that reader must not only accept Sparrow's interpretation of the theory, but also and more importantly, that reader must believe that agent-based virtue theory already contains the right answer to the terraforming question. If Sparrow's goal is to advance the practical debate, then his choice of the theory-centered mode has limited his audience to a tiny fraction of those people interested in the terraforming question. This is in part because the audience of the terraforming-curious is largely composed of people who have not studied Slote and have no stake in disagreements between advocates of agent-based and eudaimonistic virtue theories. But even among specialists in moral theory, a small minority are avowed Slote-ians. Hardly anyone in Sparrow's intended audience is willing to accept a key premise on which his argument relies: his endorsement of agent-based virtue ethics as containing the answer to the terraforming question. Though Sparrow's paper is an insightful and exciting way to elaborate agent-based

virtue ethics and to test its adaptability for extraterrestrial concerns, there are few in the world for whom it could provide a reason to reject terraforming.

Despite the name, "applied ethics" in the theory-centered mode is fundamentally a theoretical undertaking. Such work cannot directly contribute to debates about practical controversies, because all arguments in the theory-centered mode appeal to a premise---the endorsement of a specific theory as the source of the correct answer to the question at hand---that is more controversial than the question itself. Social consensus concerning the moral permissibility of mining the moon or terraforming Mars, for example, is more readily achievable than social consensus around Slote's virtue theory or Attfield's theory of intrinsic value.¹

Theoretical work, including applied ethics in the theory-centered mode, is important. So too is practical ethics. Space ethics, an area of inquiry devoted to ethical questions that are rapidly shifting from hypothetical to concrete, would do well to re-balance its output in favor of the practical-controversy-centered mode of argument. This paper is a contribution to that effort. I identify two pre-theoretic moral principles that I expect most readers either already accept, or will accept once I've described them. Rather than use these widely held beliefs as inputs for theory construction, I argue directly from them to the conclusion that colonizing Mars is morally wrong. The first argument appeals to a broadly accepted principle of scientific conservation. (I preface this argument with preliminary considerations in support of the claim that scientific curiosity is the only compelling reason for humans to explore Mars.) The second argument appeals to a practical principle governing our interactions with wilderness.

1. Preliminary: Why *should* we colonize Mars?

Mars is the easiest planet for Earthlings to reach, but it isn't exactly *easy* to get there. What reasons do we have to invest the resources required to establish a human presence on Mars? I identify five reasons offered by advocates of colonization, and argue that one alone withstands reflective scrutiny.

1.1 We should colonize Mars to exploit its natural resources.

The earth is finite, and we will eventually exhaust its natural resources. When that happens, we'll have to turn to space for more (Schwartz 2011; Lewis 1997; Hartmann 1984). Mars is rich in many resources that are important on Earth (Barlow 2008, 91), and models of Martian geology suggest these resources are probably grouped in deposits that make them mineable (West and Clarke 2010). We should therefore colonize Mars as an instrumentally necessary step toward the goal of effectively exploiting its resources.

¹ See Milligan (2016) for an argument in a similar spirit.

Reply: there are moral reasons to worry about space-mining solutions to resource shortages on Earth (Berry 1977). But we need not resort to moral arguments to reveal the failure of a resource-based justification *for colonizing Mars*. If at some point our refusal to manage Earth's resources makes it economically appealing to turn to space for more, it will *always* be cheaper to mine asteroids than Mars, because asteroids aren't stuck at the bottom of a gravity well. In fact, many resource-rich asteroids are less fuel-intensive to reach than the surface of Earth's moon---let alone the surface of Mars (Yárnoz et. al 2013). Mar's resources provide no economic justification for colonization.

1.2 We should colonize Mars to fulfill our pioneering nature.

The drive to explore, to expand, to pioneer, is a deep feature of human nature. Settling frontiers is what humans do; it's who we are. Colonizing Mars is therefore a question "of reaffirming the pioneering character of our society" (Zubrin 2012, xxv) and failing to colonize Mars "constitutes failure to live up to our human nature and a betrayal of our responsibility as members of the community of life itself" (Zubrin 2012, 267).

Reply: Zubrin appears to believe that humans are innately driven to expand, and that this drive is noble. But the claim that we have an innate drive to discover and subdue wilderness appears to be descriptively false (Delgado 2011; Schwartz 2017), and to characterize such a drive as noble is morally dubious. Though expanding *knowledge* is usually an ennobling undertaking, the lessons of centuries tell us that expanding our footprint is (at best) of ambiguous moral valence (Limerick 1992; Billings 1997).

More generally, the exclamation "it's what humans do!" has never been a good justification for anything, anywhere, ever. Humans apparently harbor drives not only for expansion, but also for revenge, war, sexual assault, scapegoating the socially marginalized, exploiting the downtrodden, denying the humanity of culturally unfamiliar people, stigmatizing disabled people, and arrogating to ourselves every kind of resource beyond all reason. Zubrin and others who endorse some version of the pioneer argument owe us an explanation of why humans should unleash expansionary drives, when we ought to keep a tight leash on so many others.

1.3 We should colonize Mars to secure fresh opportunities for experiments in living.

Says Freeman Dyson: "It is in the long run essential to the growth of any new and high civilization that small groups of men can escape from their neighbors and from their governments, to go and live as they please in the wilderness. A truly isolated, small, and creative

society will never again be possible on this planet.”² Settlements in space are thus our only realistic opportunity to experiment with alternative social and political structures (Hartmann 1984). Of all possible space destinations, Mars is the most welcoming. We should colonize Mars because such a colony would provide a clean break with history, and for the first time in a long time give a new generation the opportunity to form a fresh and vigorous society that will replenish the human spirit (Zubrin 2012, 324--325).

Reply: Suppose, for the sake of argument, that as a matter of descriptive fact, small groups of people must live in wilderness in order to re-invent institutions, loosen the strictures of custom, and experiment with new social organizations. There are two related problems with citing the need for fresh opportunities for experiments in living *as a reason to colonize Mars*. The first is that there are plenty of isolated places on Earth that have yet to be settled. It might, perhaps, be true that there are no hospitable places left unexplored, but our planet presents us with a cornucopia of forbidding possibilities: raft cities in international waters, settlements deep in unpopulated deserts, wilderness areas within failed states, Arctic tundra, and Antarctic ice shelves. Every one of these places is much, *much* friendlier to human bodies than is the surface of Mars.³ If accomplishing isolation in pursuit of experiments in living were some kind of moral or prudential imperative, the instrumentally rational way to discharge that obligation would be to settle isolated regions of Earth, not to colonize Mars.⁴

And so we arrive at the second problem: why think that there is a moral or prudential obligation to settle new wilderness *so as to rejuvenate the culture via wilderness-mediated experiments in living*? The American pioneers Zubrin lionizes were not responding to any such imperative; they were responding to more immediate economic and social pressures. To the extent that the social and institutional patterns they ended up with differed from those they left behind, this was an effect of their decision to move, not its cause.

The persistent non-existence of a long-planned libertarian colony of seasteading rafts (Robinson 2014), to pick one example from the list of unexecuted libertopian schemes, suggests that even among those who aver a Zubrinian obligation to experiment with living, that obligation is a weak one. If the obligation to isolate a small community in wilderness is so easily overridden

² From an unpublished 1958 manuscript, “A Space Traveler’s Manifesto,” quoted in Dyson (2002, 186).

³ Mars’s atmosphere is 95% carbon dioxide—poisonous to humans. There is so little of it that no moisture can remain liquid at human body temperature. (Brief exposure on the surface of Mars would result in the moisture on your eyes, skin, and lungs rapidly boiling away.) The surface of Mars is pummeled by radiation more severe than anywhere on Earth. Also, it’s cold.

⁴ Zubrin anticipates this objection and responds that isolated spots on Earth are inadequate because “no matter how remote or hostile the spot on Earth, the cops are too close. If people are to have the dignity that comes with making their own world, they must be free of the old” (2012, 325). This is a puzzling response, given that the cops were also close to the American colonists and pioneers that provide his model. A seasteading raft colony would surely be farther from the sheriff than were settlers in the Old West.

that it cannot motivate a seasteed in international waters, it cannot be the moral or prudential impetus for colonizing Mars.

1.4 We should colonize Mars as a backup planet.

We have an obligation to ensure the long-term survival of our species. We ought, then, to expand beyond Earth, because once humans are established elsewhere in the heavens, our species will no longer be vulnerable to catastrophes on Earth. Since Mars is by far the best prospect for an autonomous human colony in the foreseeable future, we should settle it. As Larry Niven once said, according to Arthur Clarke, “the dinosaurs became extinct because they didn't have a space program. And if we become extinct because we don't have a space program, it'll serve us right.”⁵

Many people celebrated for their smarts endorse this argument for colonizing Mars. This is Elon Musk's reason for pushing for Mars (Urban 2015). Carl Sagan (1994, 377), Ray Bradbury (Bradbury et al 1973, 133), Stephen Hawking (Highfield 2006), and Paul Davies (2004) have all endorsed some version of the species-survival argument for space colonies. Everyone on this list agrees that establishing an autonomous colony on Mars is a rational response to the moral imperative to hedge against the risk of an extinction-level catastrophe on Earth.

Reply: The range of species-level threats addressed by a Mars colony is relatively narrow (York 2002). A Mars colony would not insure against large-scale threats to the solar system, such as nearby supernovae, invading extraterrestrials, or an early expansion of the sun. Nor would it insure against threats we pose to ourselves, such as war and environmental destruction. We carry these threats to ourselves everywhere we go, and we would carry them with us to Mars.

A Mars colony would only insure against externally imposed large-scale environmental threats specific to Earth. A colony on Mars would be unmolested by, for example, a Chicxulub-scale asteroid or comet strike on Earth. But is a Mars colony the best way to hedge against this risk?

First, note that while it's relatively easy to imagine an asteroid or comet impact knocking civilization back a few hundred years, it's genuinely difficult to imagine a *sapiens-extincting* impact. Contra-Niven, Chicxulub didn't kill the dinosaurs because they lacked a space program; it killed them because they lacked blankets.

Now, imagine that you have no vested interest in colonizing Mars, and your concern is to do a flinty eyed cost/benefit analysis of various proposals to hedge against asteroid-based threats to civilization and species survival. You're presented with the following options. The first is the Musk option: invest the resources required to establish a million-person settlement on Mars that might possibly be self-sustaining in the event of a civilization-ending asteroid strike on Earth.

⁵ <https://www.clarkefoundation.org/about-sir-arthur/sir-arthurs-quotations/>

Option two: invest in detection and re-direct capabilities for near-Earth objects. Invest in seed arks and hardened knowledge repositories and energy sources. With proper investment we could come close to eliminating the chance of a civilization-ending, let alone a species-ending impact. This course would be cheaper *and* more effective than establishing a Mars colony. Even if planetary defenses fail and a strike happens, there is virtually nothing an asteroid could do to Earth that would make it as hostile to human life as Mars already is; even Chicxulub II would leave Earth with non-lethal atmospheric pressure, a radiation-blocking magnetic field, and oxygen, all of which Mars lacks.

Musk and others promote Mars colonies as required by a cost/benefit analysis of the best way to discharge our obligation to ensure the survival of our species. But their cost/benefit analysis only appears rational because they have carefully loaded the comparison scenarios in a way that guarantees a pro-colonization conclusion. Musk is surely right that colonizing Mars is more prudent, from a species-preservation perspective, than sitting on our hands. But once we supply a third option it is clear that *if* there is a moral obligation to take instrumentally effective steps to safeguard the species,⁶ then investment in planetary defense and civilization protection, not Mars colonization, is what is morally required (Baum 2016).

This conclusion is not a consequence of pinchpenny aerospace budgets forcing a hard choice between promising options. If the goal is species survival, and given that the Martian environment is much less survivable than even a post-strike Earth would be, then there is no remotely realistic budget point at which the marginal dollar would be more effectively spent on Mars colonization than on protecting Earth and the creatures and civilizations that evolved to live within its shelters.

1.5 We should colonize Mars in order to learn the answers to important scientific questions.

Freeman Dyson, once again: “There are more things in heaven and earth than are dreamed of in our present-day science. And we shall only find out what they are if we go out and look for them” (quoted in Dyson 2002, 186).

This, finally, is a genuine reason to go to Mars. The previous subsections have all highlighted values that, if worth pursuing at all, are most effectively pursued on Earth. But Mars’s *scientific* value provides a genuine reason to go there, because questions about Mars most certainly cannot be better answered here on Earth.⁷ In order to understand Mars’s history, geology, geography, weather, chemistry, and so on, we have to go there and look.

⁶ It is not self-evident that there is any such duty to promote species survival. For defenses of the claim see Schwartz (2011), Munevar (2014), and Milligan (2015, chapter 5).

⁷ These claims might be considered a Mars-specific instance of Schwartz’s general argument that in the near- and medium-term, scientific exploration trumps development as a justification for any human use of space (Schwartz 2014).

Mars is also an excellent destination at which to pursue broader scientific questions about the nature and scope of life. Is Mars currently abiotic? Has it always been? If there is no evidence of present or past Martian life, how seriously should we take the possibility that life on Earth is unique in the universe? If we do find evidence of life, is it built on DNA and RNA? If so, which version of the panspermia hypothesis does that evidence support? If Martian life is fundamentally different, what does that tell us about the prospects for the spontaneous appearance of life in other environments and our own odds of survival (Bostrom 2008)? These are huge, tectonic questions that Mars can potentially answer, and it's our best bet, in our lifetimes, for answering them.

We can learn things on Mars that cannot be learned on Earth, and some of the discoveries promised on Mars would reverberate through a variety of disciplines. That's a powerful reason in favor of studying Mars. In the following section I argue that the same scientific value that gives us good reason to *study* Mars gives us moral reason not to *colonize* it.

2. The Principle of Scientific Conservation

Some scientific investigations do not alter their object of study. (Observing the migratory patterns of birds, for example, doesn't affect the birds observed.) Some scientific investigations destroy the object of study. (Performing an elemental analysis of a rock using an ICP-MS machine requires grinding and dissolving the rock.) Between the extremes of no contact and total destruction is a spectrum of investigatory invasiveness.

While ignoring the large and vague middle of the spectrum, we can reasonably easily identify a group of minimally invasive techniques, which scarcely alter the object of investigation; and we can reasonably easily identify a group of significantly invasive techniques, which profoundly alter the object of investigation. There are *moral* constraints on the use of destructive or significantly invasive techniques; some things ought not be damaged or destroyed in the name of answering empirical questions about them. I propose the following principle as a rough guide to the permissibility of significantly invasive scientific investigation.

The Principle of Scientific Conservation: Destructive or significantly invasive investigation of an object of scientific interest is only morally permissible when 1) significantly invasive investigation does not threaten the scientific or non-scientific values instantiated in that object *and* 2) no adequate alternatives to significantly invasive investigation are available.

The Principle of Scientific Conservation is not a *theory* of ethics, intrinsic value, or anything else. It is, rather, a pre-theoretic principle providing guidance in a particular domain. Like all such principles, it must be understood as providing *pro tanto* guidance; it identifies a wrong-making feature of some scientific investigations, but can't, itself, decisively settle the question of whether an investigation is wrong all things considered. (If destructive investigation

in violation of the principle were the only way to generate a vaccine that would save millions of lives, it's probably right, all things considered, to proceed with the investigation.) The principle effectively says: "any principle-violating investigation is impermissible unless the Principle of Scientific Conservation is outweighed by a countervailing, and more important, moral value."

2.1 Illustrations of the Principle of Scientific Conservation

A few examples will illustrate the plausibility of the claim that a scientific investigation that violates either clause of the principle is *pro tanto* morally wrong.

*A real-world illustration of a violation of clause #1: Currey meets Prometheus.*⁸ In 1964, Donald Currey, a graduate student using tree rings to study the Little Ice Age of about 500 years ago, attempted to take a core sample of an ancient-looking bristlecone pine in Nevada. Unfortunately, his borer stuck fast in the trunk. He cut down the tree to retrieve his borer, sectioned the trunk, and counted its rings. To his horror, he counted 4,844 rings, which made Prometheus, as the tree was subsequently named, the oldest known living organism on Earth. When Prometheus sprouted in Nevada, the City of Troy was newly founded, hieroglyphic writing had just been invented in Egypt, and some neolithic tribes in England were beginning to grumble about the build quality of their wood and dirt version of Stonehenge.

In virtue of being the Oldest Known Organism on Earth, Prometheus had aesthetic, historical, and other non-scientific values that should have been preserved. Prometheus also could have been a key subject for scientific investigations other than Currey's. In felling the tree, he foreclosed those possibilities.

Currey had no idea what he was cutting down when he cut it down; he *unwittingly* violated the first clause of the Principle of Scientific Conservation.⁹ The widespread moral outrage directed at him when the story broke, and the personal burden of guilt he apparently carried for the rest of his life, lends support to this claim: employing a destructive technique in violation of the Principle of Scientific Conservation is a *moral* failure.

A fanciful illustration of a violation of clause #1: Sampling Mona Lisa. Suppose a curator at the Louvre wondered where da Vinci sourced his pigments for "Mona Lisa," and so scraped off samples of every color in order to test them. The empirical question is interesting, but this is not a morally permissible method for answering it. Destructively sampling "Mona Lisa" threatens a

⁸ It's difficult to find an authoritative source on Currey's story. Since factual accuracy is not crucial to the story's role as an illustrative example, I've semi-arbitrarily chosen to rely on the version of events reported by NPR's Radiolab (Zimmer 2010).

⁹ Currey's case is also an unwitting violation of the second clause, because the minimally invasive method of a core sample was available to him.

variety of special values instantiated in the painting, and so violates the first clause of the principle.

A fanciful illustration of a violation of clause #2: Unwrapping Party. During the Edwardian era, English archaeologists periodically held what were colloquially called mummy unwrapping parties. Many of these were scientifically legitimate events, in which Egyptologists, hewing to the highest standards of practice, allowed the public to view an unwrapping that would normally have occurred in the field or in a lab. Margaret Murray, for example, perhaps the premier Egyptologist of her day, unwrapped Khnum-nakht at the Manchester Museum in 1908, in hall packed to bursting with the archeologically curious. That unwrapping party served as a kind of public outreach, allowing non-scientists a glimpse of science in action (Sheppard 2013, 136-137).

Archeologists today generally do not unwrap mummies. Most mummy-related archeological questions are answerable with dual-source CT scans, a high-resolution, entirely non-invasive medical imaging technique. This method can produce a virtual mummy with a level of detail fine enough to reveal not only jewelry and other burial artifacts, but also tattoos, dental abscesses, and arterial sclerosis.

Suppose archeologists, today, discover a new mummy. And suppose they are mainly curious about the jewelry wrapped with it. Here are two ways they could pursue their question:

Option #1: use a dual-source CT scan. It's certainly up to the task, but it's expensive, not very flashy, and there might be a wait to access the machine.

Option #2: host a Margaret Murray-style unwrapping party. Unwrapping would be cheap, fast, and flashy. It would surely spark the public's interest---they could fill auditoriums with paying customers---and in the space of a few hours, they'd have not just images of the jewelry, but the jewelry itself.

Option 1 is the only morally defensible option. Flashiness and cost aren't the salient concerns. Because there is an adequate non-invasive alternative, the second clause of the Principle of Scientific Conservation rules out the invasive option.¹⁰

Realistic examples of violations of clause #2. If you want to know the age of single aspen in a clonal colony, you ought to bore a core sample; you shouldn't cut it down. If you want to know what an owl's been eating, you ought to wait for it to throw up a pellet; you shouldn't kill it to open its stomach. If you want to know the metallurgical composition of some common 19th Century coins, you ought to use X-ray fluorescence (a common and accurate non-invasive method); you shouldn't melt them down for a fire assay. In every case, the second clause of the principle properly dictates that, because an adequate non-invasive method is available, it is (*pro tanto*) wrong to use destructive methods.

¹⁰ Mummies, being rare and historically/socially significant, also have scientific and non-scientific value that is threatened by unwrapping. A modern-day unwrapping would also violate clause 1 of the principle.

2.2 A human colony on Mars would violate the Principle of Scientific Conservation

Any human presence on Mars is likely to constitute significantly invasive or destructive investigation of the Martian environment in violation of both clauses of the Principle of Scientific Conservation.

We know that a wide variety of Earth organisms can survive on Mars. The European Space Agency has run a series of experiments on the International Space Station that expose organic and biological samples to vacuum and radiation outside the station's hull. Among the things we have learned from these experiments: spores of *Trichoderma longibrachiatum*, a common soil fungus found all over Earth, can remain viable for nearly two years exposed to vacuum and unmitigated solar radiation (Neuberger et al 2015). Black fungi native to Antarctica can survive exposure to simulated Martian conditions, and a small portion of cells can, after exposure, proliferate (Onofri et al 2015). Most lichens are impervious to the brutal conditions of total exposure to vacuum, UV, and cosmic radiation, recovering to full health within 24 hours of return from exposure (Sancho et al 2007; de la Torre et al 2010).

In accordance with international agreements, Spirit, Opportunity, Curiosity, and other robotic probes currently on the surface of Mars were assembled in a clean room, their surfaces regularly swabbed with alcohol during assembly, their heat-tolerant parts baked to kill any remaining microorganisms. Despite these cleaning protocols, we can be confident that microbial hitchhikers on landers and rovers survived the trip and are currently living on the surface of Mars (Debus 2005). Indeed, we have a roster of species we've inadvertently sent there. They are, by and large, the very sorts of hardy extremophiles that could survive indefinitely on the Martian surface (Twilley 2015). Though contamination is nearly certain, there is good reason to believe that the Earth microbes that now live on Mars cannot grow and reproduce under the conditions at their landing sites. This is in part because landers have thus far avoided the "special regions" of the planet, where scientists believe Earth organisms would not just survive, but could, perhaps, successfully reproduce (Kimineck et al 2010).

Our current contamination of Mars is probably limited to dormant microorganisms confined to the spacecraft we landed there. A human colony on Mars would be a different story. Human colonists, like all humans, would be coated in and stuffed with bacteria, yeast, and fungus. Humans on the surface of Mars would continuously inoculate the planet with new strains of Earth life, constantly sowing possible progenitors of eventual Mars-adapted life.

Seeding Mars with life from Earth violates the first clause of the Principle of Scientific Conservation. Many of the important questions about Mars concern Martian life. If we contaminate Mars with Earth life, we risk making these questions impossible to answer (McKay 2011).

There are adequate non-invasive alternatives to colonization. Robotic probes can already do excellent science and they can be carefully cleaned. Available science packages improve

every year, and an ambitious space program could massively increase the speed and flexibility of future probes were they teleoperated by crewed stations in orbit of Mars, instead of the surface of Earth (Lester 2013). It is true that even with “local” teleoperation, robotic probes will not be as fast, flexible, or flashy as human explorers would be. But then CT scans of mummies are slower and less flashy than Edwardian unwrapping parties. When adequate alternatives to invasive investigation are available, slow and un-flashy is the right thing to do. To send human colonists to do research that could be accomplished by sterile probes violates the second clause of the Principle of Scientific Conservation.

2.3 Discussion

Since the early days of space exploration, the International Council for Science’s Committee on Space Research (COSPAR) has maintained a planetary protection policy for missions to other planetary bodies. The components of the policy that protect against forward-contamination are justified in terms of risks posed to later scientific investigations,¹¹ and the policy is generally understood not in moral terms, but rather as representing a kind of professional best-practice, a way to keep different researchers and agencies from stepping on each others’ toes. For example, in an overview of current levels of contamination on and around Mars, André Debus, planetary protection advisor to CNES (France’s space agency) writes that “The fact that materials, gases and microorganisms brought by missions may jeopardize present of [sic] future scientific investigations on Mars or on Mars samples is the main risk from a scientific point of view.” He contrasts this scientific risk with ethical risks, including the threat contamination poses to astronauts (Debus 2005: 1652-1653). Catherine Conley, NASA’s planetary protection officer, likewise tends to avoid moral terms in explaining the importance of avoiding forward contamination: “It’s basic common sense.... We have to be careful not to blind ourselves with Earth life, the same way you can’t see the stars when the sun is out” (Twilley 2015).

COSPAR’s precautions against forward contamination are also generally understood as temporary, to be relaxed or eliminated once agencies get to the point of landing astronauts on bodies that could support life. According to Conley and John Rummel (chair of the COSPAR panel on planetary protection) “The expectation that humans will eventually land on Mars has been implicit in COSPAR planetary protection policy from its earliest development” (Conley and Rummel 2013: 588).

To treat planetary protection as a short-term requirement of professional best-practice underestimates the *moral* force of the Principle of Scientific Conservation.¹² In order to override

¹¹ “The conduct of scientific investigations of possible extraterrestrial life forms, precursors, and remnants must not be jeopardized.... Therefore, for certain space mission/target planet combinations, controls on contamination shall be imposed in accordance with issuances implementing this policy” (COSPAR 2002).

¹² It is relatively rare for space scientists to appeal to ethical reasons for protecting destination bodies. One important exception is COSPAR’s 2010 Workshop on Ethical Considerations for Planetary Protection

the *pro tanto* moral obligation asserted by the Principle of Scientific Conservation, we need a significant *moral* reason to go there. No such reason is currently on offer.¹³

The Principle of Scientific Conservation includes ambiguous terms. It enjoins us not to threaten the scientific or non-scientific “value” instantiated in objects of scientific interest, but tells us nothing about whose assertions of value are authoritative. Thus the principle is unhelpful in cases in which there is disagreement about the value of an object of scientific interest. Similarly, the principle asserts that invasive investigation is ruled out when “adequate” non-invasive alternatives are available. But what is the standard of adequacy? How much more expensive, slow, or limited must a non-invasive alternative be before it counts as inadequate relative to the invasive option?

These ambiguities need to be worked out before the principle can be brought to bear in areas of genuine controversy about values or adequacy. But we need not answer those questions before we apply the principle to the case of Mars colonies, because there is no genuine controversy about values or adequacy in this case. Everyone urging colonies as an effective means of supporting scientific research already acknowledges that Mars has immense scientific value. And though some people chafe at the sleepy rolling speed and limited flexibility of robotic probes (Crawford 2012), those probes are orders of magnitude cheaper than human explorers, they have the same flight time to Mars and much longer potential mission durations, and there are few or no empirical questions about Mars we couldn’t design a probe to answer (Clements 2009; Weinberg 2013). Under no plausible specification of adequacy could a non-invasive technique that gathers the desired data in a broadly similar time-frame and at cheaper cost than its invasive competitor count as inadequate.

3. The Tread Lightly Principle

The Principle of Scientific Conservation entails that humans should not colonize Mars. This is not the only reason to avoid the planetary contamination colonization would bring. In this section, I introduce a moral principle governing appropriate human behavior in wilderness. This principle, too, rules out colonies on Mars.

in Space Exploration, which recommended that COSPAR amend its planetary protection policy to include some ethical language in its preamble (Rummel et. al. 2012). The workshop treated ethical protections as a distinct category from science protections, and COSPAR has thus far declined to amend its planetary protection policy to include any mention of ethics.

¹³ Kelly Smith rejects absolutist protections of Mars, arguing that “it is possible, in principle, for human interests to overbalance those of Martian microbes in some circumstances” (2016: 207). He declines, however, to identify a concrete use of Mars that morally should override microbial preservation. I share Smith’s suspicion of absolutist principles. *Pro tanto* principles are more plausible in part because they *can* be overridden, though not by a promissory note. That compelling reasons to contaminate Mars *could* exist is no challenge to the *pro tanto* constraints asserted by the Principle of Scientific Conservation. To override the principle, we need to identify an actual value that outweighs it.

3.1 Three cases in search of an explanation.

Litter in the Boundary Waters. The Boundary Waters Canoe Area on the Minnesota/Canada border is a protected wilderness area. There are no roads; no motorized vehicles are permitted on land or in the water. Visitors may leave nothing behind, and may not carry out anything they find there. Those rules have worked well enough that, by all accounts, it isn't just easy, it's often difficult to avoid setting up camp in spots that give no evidence of previous human presence.

Imagine a group of canoers on a small lake deep in the Boundary Waters. One of them finishes drinking from a plastic water bottle and proceeds to sink it in the lake. I expect you judge this is not morally permissible, even if the litterer is very careful to sink it reliably, in a deep part of the lake, so that it is vanishingly unlikely that any other canoers would ever discover it.

Modifying Goblin Valley. Goblin Valley State Park in Utah features weathered rock formations, many millions of years in the making, including canyons, mesas, hoodoos, and balancing rocks. In 2013 the Internet was briefly enraged when a group of obnoxious Boy Scout leaders posted a video of themselves toppling a boulder from the top of a hoodoo. "We have just modified Goblin Valley," chortles the man holding the camera (Botelho and Watkins 2014).

When the video went viral, moral condemnation of the modifiers of Goblin Valley was near-universal and the Boy Scouts promptly expelled them. I expect you, too, judge that they were wrong to topple that balancing rock.

Wrecking a crystalline cave. Imagine a group of skilled spelunkers, through a lucky accident, discovers a remote and challenging cave. They climb deep into the earth, besting challenges few cavers could, and eventually find themselves in a vast vault, covered in crystalline stalactites. Suppose they undertook to smash every stalactite in a juvenile bacchanal of destruction. I expect you judge that this celebratory destruction is not morally permissible, even if the cave is so remote and so difficult to explore that no other climbers would ever discover it.

3.2 The "Tread Lightly" principle as best explanation of the described cases

Our judgements in these cases cannot be explained by direct appeal to some popular theories of environmental value. Conservationist-style direct appeal to harm done to other or future *people*, fails to explain at least two of the cases. We can declare littering in the Boundary Waters wrong before we establish whether or not that litter will be discovered by future hikers. Even if the spelunkers are right that no future explorers would discover the crystalline cave, they're doing something wrong when they destroy it.

Nor can the wrongness of these actions be explained by biocentric or ecocentric appeal to violations of the intrinsic value of living things or ecosystems. No components of Goblin

Valley's *ecosystem* were affected by the relative positions of the hoodoo and its pedestal rock. In the case of the spelunkers, destruction is wrong even in a cave so deep it is abiotic, and so has no life to harm.

Rather than appeal directly to a theory to explain what's wrong with the behavior of the characters in these cases, I suggest we seek a pre-theoretic principle governing our interactions with wilderness. In fact, the Boy Scouts have already gone a long way toward explaining these cases in their long-standing injunction to "leave no trace" when visiting wilderness: our described characters all acted wrongly in leaving a trace where they shouldn't have.

A bit of clarification is sufficient to turn the Boy Scouts' handbook guidance into a plausible pre-theoretic principle. "Leave no trace" cannot mean "leave no evidence of human presence," for that would be too weak. Had the modifiers of Goblin Valley not posted their video, no one would have known they were there. It was the video, not the destructive act, that provided evidence of their presence. But the destruction would have been wrong even if they hadn't filmed it.

Nor can "leave no trace" mean "have zero impact," for that would be too strong. People can visit wilderness without having done anything wrong, but no one can spend time in any environment while having literally no impact on it.

The injunction to leave no trace is best understood as suggesting a kind of counterfactual comparison. It means that after visiting a new environment, the traces you leave should, before long, be indistinguishable from counterfactual worlds in which you didn't visit. "Zero impact" most plausibly means "whatever impact you do make should be indistinguishable from the effects of natural processes after a suitable period of time." We should tread lightly enough on wilderness that natural processes quickly erase our footprints.

The Tread Lightly Principle: When we visit wilderness, we have a moral obligation to conduct ourselves in such a way that the impact of our presence is indistinguishable, after a suitable period of time, from counterfactual worlds in which we didn't visit that wilderness.

Like the Principle of Scientific Conservation, Tread Lightly is a *pro tanto* moral principle---it identifies a wrong-making feature of some interactions with wilderness, but does not by itself establish whether a given interaction with wilderness is wrong, all things considered. Treading heavily can sometimes be warranted by countervailing and weightier moral considerations. (Landing a helicopter in the Boundary Waters would be morally permissible were that the only way to rescue a group of stranded children.) But, as with the Principle of Scientific Conservation, we need good *moral* justification for overriding the Tread Lightly Principle.

3.3 A Mars colony could not tread lightly on the Martian environment

For the same reasons discussed in Section 2.2, it would be nearly impossible for a human colony to tread lightly on the Martian environment. If Mars is currently abiotic, then the introduction of Earth microbes will likely convert Mars into a biotic environment. That would fundamentally alter the planet, compared to the counterfactual worlds in which we did not settle there.

In a thriving ecosystem, homeostatic pressures make it relatively easy to tread lightly in wilderness. (Someone who responsibly treks the Boundary Waters, for example, can reasonably expect that a month after they've left, the ecosystem will be no different than if they hadn't visited at all.) If Mars is currently biotic, we have little reason to believe it is a thriving ecosystem, teeming with the varieties of interdependent life that generate tendencies toward homeostasis. In the worse cases, Earth microbes could prove invasive, threatening the survival of native life. But even if introduced life could coexist with Martian life, that introduced life would leave the planet permanently different from the counterfactual world in which its biota was left alone.

Whether or not Mars is currently biotic, introducing Earth life would violate the Tread Lightly Principle.

3.4 Discussion

As it stands, the Tread Lightly Principle is incompletely developed. Before it could be usefully applied to hard cases, we need answers to the following questions. 1. How long is the “suitable period of time” that should pass before we make the counterfactual comparison? (Too short---a few minutes---and no interaction with wilderness would qualify as treading lightly. Too long---a million years---and scandalous abuses of wilderness would count as treading lightly.) 2. Should the counterfactual worlds used for comparison include environmental effects of other humans, or only the effects of natural processes? (If the impact of my interaction with wilderness would be erased not by natural processes, but rather by the activities of other people, does that count as treading lightly?) 3. What counts as wilderness? Philosophical definitions of the concept are contested. I intend “wilderness” in the colloquial sense, as picking out *undeveloped*, or *minimally developed* land. But the question still remains: at what level of development does the Tread Lightly Principle stop being relevant, because the developed land has ceased to be wilderness?

Though these questions need answers before Tread Lightly is useful in a broad range of cases, the principle is applicable to the question of Mars colonies before we answer any of them. That's because: 1. A Mars colony would very likely *permanently* alter the Martian environment, so fixing the duration of “a suitable period of time” is not necessary. 2. There are no existing human activities on Mars that could erase the impact of a new colony there. 3. Mars is currently very nearly pristine, and so is a limiting case of wilderness; if anything counts as wilderness in the colloquial sense, Mars does.

4. Concluding Remarks

I have introduced two pre-theoretic, *pro tanto* moral principles---specific principles governing action in specific domains. The Tread Lightly Principle holds that we ought to tread lightly when we visit wilderness. The Principle of Scientific Conservation holds that we should avoid significantly invasive or destructive research methods if they would threaten the value of the subject of study, or if there are minimally invasive methods available. Because a colony on Mars would very likely contaminate Mars with microorganisms from Earth, fundamentally altering the Martian environment forever, both principles entail that colonizing Mars is morally wrong.

If I am right that these pre-theoretic principles are broadly accepted, then one of the tasks of a theory of normative ethics will be to explain and justify them in theoretical terms. The ability to account for widely held, credible pre-theoretic principles---what Aristotle would have called *endoxa*---is, after all, an adequacy condition of any theory of ethics. It is, for example, easy to justify the Principle of Scientific Conservation in rule-utilitarian terms, as this principle, if adopted as a rule, seems likely to generate the best consequences. The Tread Lightly Principle is similarly easy to justify in virtue ethical terms. But if these pre-theoretic principles are plausible, then other theories of ethics will have to account for them as well.¹⁴ Adopting the practical-controversy-centered mode of applied ethics, as I have done here, is not to repudiate theory; it is to make a different kind of contribution.

Critics of my arguments might accept the principles on which they are based, but argue that they do not, in fact, rule out Mars colonies. The consensus among space scientists is that Earth organisms pose a contamination risk to Mars. That consensus is not unanimous. Fairén and Schulze-Makuch (2013), for example, argue that if Earth organisms can survive on Mars, they are probably already there as a result of lithopanspermic transmission at some point in the 3.8-billion-year history of life on Earth. If there aren't currently Earth organisms on Mars, then that suggests that the Martian environment reliably kills Earth life. It follows that we need not fuss so much about killing microorganisms before they land on Mars; Mars will finish the job for us.¹⁵

Suppose, for the sake of argument, that the scientific consensus is wrong, and Fairén and Schulze-Makuch are right; suppose it will be easy for colonists to protect Mars from microbial contamination. The following two consequences still follow from the principles I've introduced.

First, preserving the Martian environment should be a controlling factor in every decision we make while there. Even if our current protocols are more conservative than they need to be to effectively protect Mars, effective protection is morally required; it is not a secondary objective, not a stretch goal, not icing on the cake. Any benefit we'd like to glean from Mars must develop within the side-constraints of scientific conservation and wilderness preservation.

¹⁴ Wilks (2016) could be re-purposed as a Kantian account of the Tread Lightly Principle.

¹⁵ This argument is rebutted by Conley and Rummel (2013).

Second, *terraforming* Mars, that beloved topic of science fiction writers, should remain, forever, science fiction. Any presence we establish on Mars should tread lightly and be minimally invasive, and that is incompatible with terraforming the planet.

Both of these conclusions stand, even if it turns out, against consensus expectations, that basic biocontainment protocols will be sufficient to keep Mars pristine. To reject these conclusions---to begin terraforming, or otherwise to ignore issues of planetary protection, as Musk and Hawking and Zubrin and the United Arab Emirates and so many others do---requires direct critical engagement of the Principle of Scientific Conservation and the Tread Lightly Principle.

Of course it is better, when making weighty and irreversible decisions, to provisionally accept the consensus view of scientists working in the field. Fairén and Schulze-Makuch are probably wrong, and a human presence on Mars would probably contaminate the planet with new life from Earth. Absent successful critical engagement of the Tread Lightly Principle and the Principle of Scientific Conservation we should refuse, on moral grounds, to establish any human presence on Mars.

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REFERENCES

Attfield, Robin (1981) 'The Good of Trees'. *Journal of Value Inquiry*, 15(1), 35–54.

Barlow, Nadine (2008) *Mars: An Introduction to Its Interior, Surface and Atmosphere*. Cambridge: Cambridge University Press.

Baum, Seth (2016) 'The Ethics of Outer Space: A Consequentialist Perspective'. In Schwartz and Milligan (eds.), *The Ethics of Space Exploration* (Springer), 109–123.

Berry, Wendell (1977) 'Comments on O'Neill's Space Colonies'. In Brand (ed.), *Space Colonies* (Harmondsworth: Penguin).

Billings, Linda (1997) 'Frontier Days in Space: Are They Over?'. *Space Policy*, 13(3), 187–190.

- Bostrom, Nick (2008) 'Where Are They?'. *Technology Review*, 111(3).
- Botelho, Greg and Watkins, Tom (2014) Ex-Boy Scout Leaders Involved in Pushing over Ancient Rock Charged. CNN. Available at <http://www.cnn.com/2014/01/31/us/utah-boulder-boy-scouts/index.html> [3 June 2017].
- Bradbury, Ray, Clarke, Arthur, Murray, Bruce, Sagan, Carl and Sullivan, Walter (1973) *Mars and the Mind of Man*. New York: Harper and Row.
- Clements, David (2009) 'Human Spaceflight: Science or Spectacle?'. *Physics World*, 22(11), 16.
- Cockell, Charles (2005) 'Planetary protection—A Microbial Ethics Approach'. *Space Policy*, 21(4), 287–292.
- Conley, Catharine and Rummel, John (2013) 'Appropriate Protection of Mars'. *Nature Geoscience*, 6(8), 587–588.
- COSPAR (2002) *COSPAR Planetary Protection Policy*.
- Crawford, Ian (2012) 'Dispelling the Myth of Robotic Efficiency: Why Human Space Exploration Will Tell Us More about the Solar System than Will Robotic Exploration Alone'. *Astronomy and Geophysics*, 53(2), 2.22-2.26.
- Davies, Paul (2004) *Life (and Death) on Mars*. The New York Times. Available at <http://www.nytimes.com/2004/01/15/opinion/life-and-death-on-mars.html> [22 May 2017].
- Debus, André (2005) 'Estimation and Assessment of Mars Contamination'. *Advances in Space Research*, 35(9), 1648–1653.
- Delgado, Laura M. (2011) 'When Inspiration Fails to Inspire: A Change of Strategy for the US Space Program'. *Space Policy*, 27(2), 94–98.
- Dyson, George (2002) *Project Orion: The True Story of the Atomic Spaceship*. New York: Henry Holt.
- Fairén, Alberto and Schulze-Makuch, Dirk (2013) 'The Overprotection of Mars'. *Nature Geoscience*, 6(7), 510–511.
- Hartmann, William (1984) 'Space Exploration and Environmental Issues'. *Environmental Ethics*, 6(3), 227–239.
- Highfield, Roger (2006) *We Must Leave Earth, Says Hawking*. The Telegraph. Available at <http://www.telegraph.co.uk/news/uknews/1535661/We-must-leave-Earth-says-Hawking.html> [22 May 2017].

Kminek, G., Rummel, J. D., Cockell, C. S., Atlas, R., Barlow, N., Beaty, D., Boynton, W., Carr, M., Clifford, S., Conley, C. A., Davila, A. F., Debus, A., Doran, P., Hecht, M., Heldmann, J., Helbert, J., Hipkin, V., Horneck, G., Kieft, T. L., Klingelhofer, G., Meyer, M., Newsom, H., Ori, G. G., Parnell, J., Prieur, D., Raulin, F., Schulze-Makuch, D., Spry, J. A., Stabekis, P. E., Stackebrandt, E., Vago, J., Viso, M., Voytek, M., Wells, L. and Westall, F. (2010) 'Report of the COSPAR Mars Special Regions Colloquium'. *Advances in Space Research*, 46(6), 811–829.

Korsgaard, Christine (2004) 'Fellow Creatures: Kantian Ethics and Our Duties to Animals'. *Tanner Lectures on Human Values*, 24, 77–110.

Lee, Keekok (1994) 'Awe and Humility: Intrinsic Value in Nature. Beyond an Earthbound Environmental Ethics'. *Royal Institute of Philosophy Supplements*, 36, 89–101.

Lester, Dan (2013) 'Achieving Human Presence in Space Exploration'. *Presence*, 22(4), 345–349.

Lewis, John (1997) *Mining the Sky: Untold Riches from the Asteroids, Comets, and Planets*. New York: Basic Books.

Limerick, Patricia (1992) 'Imagined Frontiers: Westward Expansion and the Future of the Space Program'. In Byerly (ed.), *Space Policy Alternatives* (Boulder: Westview Press), 249–262.

McArthur, Dan and Boran, Idil (2004) 'Agent-Centered Restrictions and the Ethics of Space Exploration'. *Journal of Social Philosophy*, 35(1), 148–163.

McKay, Christopher (2011) 'The Search for Life in Our Solar System and the Implications for Science and Society'. *Philosophical Transactions of the Royal Society of London*, 369(1936), 594–606.

Milligan, Tony (2015) *Nobody Owns the Moon: The Ethics of Space Exploitation*. Jefferson: McFarland.

——— (2016) 'Space Ethics Without Foundations'. In Schwartz and Milligan (eds.), *The Ethics of Space Exploration* (Springer), 125–134.

Munévar, Gonzalo (2014) 'Space Exploration and Human Survival'. *Space Policy*, 30(4), 197–201.

NASA, JPL Planetary Protection - Mars Science Laboratory. Available at <https://mars.nasa.gov/msl/mission/technology/insituexploration/planetaryprotection/> [3 June 2017].

Neuberger, Katja, Lux-Endrich, Astrid, Panitz, Corinna and Horneck, Gerda (2015) 'Survival of Spores of *Trichoderma Longibrachiatum* in Space: Data from the Space Experiment SPORES on EXPOSE-R'. *International Journal of Astrobiology*, 14(1), 129–135.

Onofri, Silvano, de Vera, Jean-Pierre, Zucconi, Laura, Selbmann, Laura, Scalzi, Giuliano, Venkateswaran, Kasthuri J., Rabbow, Elke, de la Torre, Rosa and Horneck, Gerda (2015) 'Survival of Antarctic Cryptoendolithic Fungi in Simulated Martian Conditions On Board the International Space Station'. *Astrobiology*, 15(12), 1052–1059.

Robinson, Edward (2014) For Libertarian Utopia, Float Away on 'Startup' Nation. Bloomberg Markets. Available at <https://www.bloomberg.com/news/articles/2014-05-30/for-libertarian-utopia-float-away-on-startup-nation> [20 May 2017].

Rummel, John, Race, Margaret and Horneck, Gerda (2012) 'Ethical Considerations for Planetary Protection in Space Exploration: A Workshop'. *Astrobiology*, 12(11), 1017–1023.

Sagan, Carl (1994) *Pale Blue Dot: A Vision of the Human Future in Space*. New York: Random House.

Sancho, Leopoldo G., de la Torre, Rosa, Horneck, Gerda, Ascaso, Carmen, de los Rios, Asunción, Pintado, Ana, Wierzchos, J. and Schuster, M. (2007) 'Lichens Survive in Space: Results from the 2005 LICHENS Experiment'. *Astrobiology*, 7(3), 443–454.

Scherer, Donald (1988) 'A Disentropic Ethic'. *The Monist*, 71(1), 3–32.

Schwartz, James (2011) 'Our Moral Obligation to Support Space Exploration'. *Environmental Ethics*, 33(1), 67–88.

——— (2014) 'Prioritizing Scientific Exploration: A Comparison of the Ethical Justifications for Space Development and for Space Science'. *Space Policy*, 30(4), 202–208.

——— (2016) 'On the Methodology of Space Ethics'. In Schwartz and Milligan (eds.), *The Ethics of Space Exploration* (Springer), 93–107.

——— (2017) 'Myth-Free Space Advocacy Part I—The Myth of Innate Exploratory and Migratory Urges'. *Acta Astronautica*, 137, 450–460.

Sheppard, Kathleen (2013) *The Life of Margaret Alice Murray: A Woman's Work in Archaeology*. Plymouth: Lexington Books.

Singer, Peter (1972) 'Famine, Affluence, and Morality'. *Philosophy & Public Affairs*, 1(3), 229–243.

Smith, Kelly (2014) 'Manifest Complexity: A Foundational Ethic for Astrobiology?' *Space Policy*, 30(4), 209–14.

——— (2016) ‘The Curious Case of the Martian Microbes: Mariomania, Intrinsic Value and the Prime Directive’. In Schwartz and Milligan (eds.), *The Ethics of Space Exploration* (Springer), 195–208.

Sparrow, Robert (1999) ‘The Ethics of Terraforming’. *Environmental Ethics*, 21(3), 227–245.

Taylor, Adam (2017) *The UAE’s Ambitious Plan to Build a New City — on Mars*. Washington Post. Available at <https://www.washingtonpost.com/news/worldviews/wp/2017/02/16/the-uaes-ambitious-plan-to-build-a-new-city-on-mars/> [22 May 2017].

Thomas, Cathy Booth (2007) ‘The Space Cowboys’. *Time*, 169(10), 52–58.

Thomson, Judith Jarvis (1971) ‘A Defense of Abortion’. *Philosophy and Public Affairs*, 1(1), 47–66.

de la Torre, Rosa, Sancho, Leopoldo G., Horneck, Gerda, Ríos, Asunción de los, Wierzchos, Jacek, Olsson-Francis, Karen, Cockell, Charles S., Rettberg, Petra, Berger, Thomas, de Vera, Jean-Pierre P., Ott, Sieglinde, Frías, Jesus Martinez, Melendi, Pablo Gonzalez, Lucas, Maria Mercedes, Reina, Manuel, Pintado, Ana and Demets, René (2010) ‘Survival of Lichens and Bacteria Exposed to Outer Space Conditions – Results of the Lithopanspermia Experiments’. *Icarus*, 208(2), 735–748.

Twilley, Nicola (2015) ‘Meet the Martians’. *The New Yorker*. Available at <http://www.newyorker.com/tech/elements/meet-the-martians> [3 June 2017].

Urban, Tim (2015) ‘How (and Why) SpaceX Will Colonize Mars’. *Wait But Why*. Available at <http://waitbutwhy.com/2015/08/how-and-why-spacex-will-colonize-mars.html> [10 May 2017].

Weinberg, Steven (2013) ‘Response: Against Manned Space Flight Programs’. *Space Policy*, 29(4), 229–230.

West, Michael and Clarke, Jonathan (2010) ‘Potential Martian Mineral Resources: Mechanisms and Terrestrial Analogues’. *Planetary and Space Science*, 58(4), 574–582.

Wilks, Anna Frammartino (2016) ‘Kantian Foundations for a Cosmocentric Ethic’. In Schwartz and Milligan (eds.), *The Ethics of Space Exploration* (Springer).

Wilson, Jim (2016) *Journey to Mars Overview*. NASA. available at <http://www.nasa.gov/content/journey-to-mars-overview> [22 May 2017].

Yárnoz, D. García, Sanchez, J. P. and McInnes, C. R. (2013) ‘Easily Retrievable Objects among the NEO Population’. *Celestial Mechanics and Dynamical Astronomy*, 116(4), 367–388.

York, Paul Francis (2002) ‘The Ethics of Terraforming’. *Philosophy Now*, 38, 6–9.

——— (2005) *Respect for the World: Universal Ethics and the Morality of Terraforming*.

York, Richard (2005) 'Toward a Martian Land Ethic'. *Human Ecology Review*, 12(1), 72.

Zimmer, Ben (2010) 'Be Careful What You Plan For'. Radiolab. Available at <http://www.radiolab.org/story/91722-be-careful-what-you-plan-for/> [6 June 2017].

Zubrin, Robert (2012) *The Case For Mars*. New York: Simon and Schuster.