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Humans Should Not Colonize Mars

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 pretheoretic 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. SpaceX CEO Elon Musk says, 'I think we should establish [human] life on another planet—Mars in particular. . . . SpaceX is intended to make that happen' (Thomas 2007). Sheikh Mohammed bin Rashid Al Maktoum, Emir of Dubai, recently announced that the United Arab Emirates' Mars 2117 project, 'integrates a vision to create a mini-city and community on Mars' (Taylor 2017). NASA says, '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?

1. 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.

The University Honors Student Association at the University of Minnesota invited me to speak on the ethics of Mars colonization at their 2017 retreat. I am grateful to the organizers and participants both for suggesting such an interesting topic and for their feedback on my presentation, which helped shape the resulting paper. Thanks to Crystal Bergstrom, Carl Hammer, Mark Stoner, Jason Swartwood, and two anonymous reviewers for feedback on drafts. Special thanks to Mark Stoner, who went to supererogatory lengths to help me gather research materials.

Applied ethics in the practical-controversy-centered mode begins by identifying a set of widely held beliefs—about cases, about pretheoretic principles, etc.—then argues that these beliefs entail conclusions readers might not have noticed. For example, the widely held belief that you are within your rights to disconnect yourself from the famous violinist in Thomson's described case entails that a right to life does not entail a right to life support (Thomson 1971); the widely accepted pretheoretic 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 noninstrumental, but not absolute, reasons for protecting trees (Attfield 1981).

At a glance, the difference between these methods is liable to be overlooked because 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 pretheoretic 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 pretheoretic 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, and then he 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, an attitude that 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', and then he 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's argument that Slotean agent-based virtue theory entails that terraforming Mars is morally wrong (Sparrow 1999). In order for a reader to be persuaded that he has provided a genuine reason against terraforming, that reader must not only accept Sparrow's interpretation of the theory, but also and more important, 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 those curious about terraforming 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 Sloteans. 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. (See Milligan (2016) for an argument in a similar spirit.)

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 rebalance its output in favor of the practical-controversy-centered mode of argument. This paper is a contribution to that effort. I identify two pretheoretic moral principles that I expect most readers either already accept or will accept once I have 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.

2. Why *Should* We Colonize Mars?

Mars is the easiest planet for Earthlings to reach, but it is not 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.

2.1 We Should Colonize Mars to Exploit its Natural Resources

Earth is finite, and we will eventually exhaust its natural resources. When that happens, we will 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.

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 are not 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). The resources of Mars provide no economic justification for colonization.

2.2 We Should Colonize Mars to Fulfill our Pioneering Nature

The drive to explore, to expand, and to pioneer is a deep feature of human nature. Settling frontiers is what humans do; it is 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 claim 'it is 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.

2.3 We Should Colonize Mars to Secure Fresh Opportunities for Experiments in Living

In an unpublished manuscript titled 'A Space Traveler's Manifesto', Freeman Dyson wrote, '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' (quoted in Dyson 2002: 186). 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 would give a new generation the opportunity to form a fresh and vigorous society that will replenish the human spirit (Zubrin 2012: 324–25).

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 reinvent 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. (The atmosphere of Mars is 95 percent 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 is cold.) 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.[1]

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

2.4 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 universe, our species will no longer be vulnerable to catastrophes on Earth. Because 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' (Clarke 2016).

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

1 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.

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 protect us 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 is relatively easy to imagine an asteroid or comet impact knocking civilization back a few hundred years, it is genuinely difficult to imagine a *sapiens-extincting* impact. Contra-Niven, Chicxulub did not 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 are 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.

Option two: invest in detection and redirect 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 nonlethal 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 procolonization 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, then investment in planetary defense and civilization protection, not Mars colonization, is what is morally required (Baum 2016). (Of course, 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: ch. 5].)

This conclusion regarding investment in planetary defense 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 on it.

2.5 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. In order to understand Mars's history, geology, geography, weather, chemistry, and so on, we have to go there and look. (This argument 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 is 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 is 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.

3. The Principle of Scientific Conservation

Some scientific investigations do not alter their object of study. (Observing the migratory patterns of birds, for example, does not 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 that scarcely alter the object of investigation, and we can reasonably easily identify a group of significantly invasive techniques that 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 morally permissible only when (1) significantly invasive investigation does not threaten the scientific or nonscientific 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 pretheoretic 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 it cannot by 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 is 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'.

3.1 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. 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 (Zimmer 2010). 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 nonscientific 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.[2] 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

2 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.

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 the *Mona Lisa* threatens a 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 a hall packed to bursting with the archeologically curious. That unwrapping party served as a kind of public outreach, allowing nonscientists a glimpse of science in action (Sheppard 2013: 136–37).

Archeologists today generally do not unwrap mummies. Most mummy-related archeological questions are answerable with dual-source CT scans, a high-resolution, entirely noninvasive 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:

Their first option is to use a dual-source CT scan. It is certainly up to the task, but it is expensive, not very flashy, and there might be a wait to access the machine.

Their second option is to 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 just a few hours, the archeologists would have not just images of the jewelry, but the jewelry itself.

The first option is the only morally defensible option. Flashiness and cost are not the salient concerns. Because there is an adequate noninvasive alternative, the second clause of the principle of scientific conservation rules out the invasive option.[3]

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 should not cut down the tree. If you want to know what an owl has been eating, you ought to wait for it to throw up a pellet; you should not kill it to open its stomach. If you want to know the metallurgical composition of some common nineteenth-century coins, you ought to

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

use X-ray fluorescence (a common and accurate noninvasive method); you should not melt them down for a fire assay. In every case, the second clause of the principle properly dictates that because an adequate noninvasive method is available, it is (*pro tanto*) wrong to use destructive methods.

3.2 A Human Colony on Mars Would Violate the Principle of Scientific Conservation

Any human presence on Mars is likely to constitute a 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 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 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 have 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 (Kminek 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 noninvasive alternatives to colonization. Robotic probes can already gather excellent data 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 crews stationed in Martian orbit instead of on Earth's surface (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 unflashy is the right way to go.

3.3 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 (Rummel et al. 2002), and the policy is generally understood not in moral terms, but rather in terms of a 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: 1652–53). 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. In order to override 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.[4]

4 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

The principle of scientific conservation includes ambiguous terms. It enjoins us not to threaten the scientific or nonscientific 'value' instantiated in objects of scientific interest, but it 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' noninvasive alternatives are available. But what is the standard of adequacy? How much more expensive, slow, or limited must a noninvasive 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 could not design a probe to answer (Clements 2009; Weinberg 2013). Under no plausible specification of adequacy could a noninvasive technique that gathers the desired data in a broadly similar time frame and at lower cost than its invasive competitor count as inadequate.

4. 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.

4.1 Three Cases in Search of an Explanation

Litter in the Boundary Waters. The Boundary Waters Canoe Area Wilderness 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 must not leave anything behind and must not carry out anything they find there. Those rules have worked well enough that, by all accounts, it is often difficult to avoid setting up camp in spots that give no evidence of any previous human presence.

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.

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 that this is not morally permissible, even if the litterer is very careful to sink the bottle reliably, in a deep part of the lake, so that it is highly 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.

4.2 The 'Tread Lightly' Principle as Best Explanation of the Described Cases

Our judgments 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 are 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 is wrong with the behavior of the characters in these cases, I suggest we seek a pretheoretic 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 should not have left one.

A bit of clarification is sufficient to turn the Boy Scouts' handbook guidance into a plausible pretheoretic 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 had been 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 had not filmed it.

Nor can 'leave no trace' mean 'have zero impact', for that would be too strong. People can visit wilderness areas without having done anything wrong, but no one can spend time in any environment and have 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 did not visit. 'Zero impact' most plausibly means that '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 areas so that natural processes quickly erase our footprints.

The Tread Lightly Principle. When we visit areas of 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 did not visit that wilderness area.

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 it 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.)As with the principle of scientific conservation, we need good *moral* justification for overriding the tread lightly principle.

4.3 A Mars Colony Could not Tread Lightly on the Martian Environment

For the reasons discussed in section 3.2, 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 would 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. (People who responsibly trek through the Boundary Waters, for example, can reasonably expect that a month after they have left, the ecosystem will be no different than if they had not visited at all.) If Mars is currently biotic, we have little reason to believe that it is a thriving ecosystem, teeming with the varieties of interdependent life that generate tendencies toward homeostasis. In the worst case, 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.

4.4 Discussion

As it stands, the tread lightly principle is not completely developed. Before it could be usefully applied to hard cases, we need answers to the following questions: First, 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.) Second, 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?) Third, 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 the tread lightly principle is useful in a broad range of cases, the principle is applicable to the question of Mars colonies before we answer any of them. First, a Mars colony would very likely *permanently* alter the Martian environment, and thus fixing the duration of 'a suitable period of time' is not necessary. Second, there are no existing human activities on Mars that could erase the impact of a new colony there. Third, Mars is currently very nearly pristine, and therefore it is a limiting case of wilderness; if anything counts as wilderness in the colloquial sense, Mars does.

5. Concluding Remarks

I have introduced two pretheoretic, *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 pretheoretic 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 pretheoretic 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 because 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 pretheoretic principles are plausible, then other theories of ethics will have to account for them as well (Wilks [2016] could be repurposed as a Kantian account of the tread lightly principle). 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 may 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 are currently no 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 that job for us (this argument is rebutted by Conley and Rummel [2013]).

Suppose, for the sake of argument, that the scientific consensus is wrong and that 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 have 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 protect Mars effectively, effective protection is morally required; it is not a secondary objective, not a stretch goal, not icing on the cake. Any benefit we would like to glean from Mars must develop within the side constraints of scientific conservation and wilderness preservation.

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 goal 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, when making weighty and irreversible decisions, it is better provisionally to 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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