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1 The rationale for settlement
Mars occupies a unique place in terms of human use of the solar system. There are two reasons for this: surface area and location. It is within reach, conveniently situated for expanding human activity to the Main Belt asteroids, and accounts for a large portion of the available surface area that we can work with (for whatever purposes).

1.1 Surface
It is by no means certain that humans will ever go anywhere beyond the Solar System. The sheer immensity of interstellar space may pose an obstacle too great to overcome. What exists here, inside the Solar System, may be all that we (and our successors) will ultimately be able to work with. Yet, we cannot use most of what is here, but only a fraction of it. After all, the Sun accounts for most of ‘what exists here,’ taking up more than 99.8% of the system’s total mass, leaving us less than 0.2% of the total mass to work with. When we think of matters in terms of surface area the prospect does not improve. Setting aside the Sun, the gas giants (Jupiter, Saturn, Uranus and Neptune) account for over 98% of the remaining surface area. This is a problem. While they are some distance away, we might still reach them without difficult-to-imagine technologies. Not now, but someday. Leaving their surfaces would, however, be much harder. Their mass is immense and their gravity-wells are deep. The energy required to climb out of them would be of a similar scale. In the cases of Neptune and Uranus this might be possible (again, not now, but in the future) but Saturn and Jupiter look prohibitively difficult. The idea of their commercial use, even using automated systems rather than flesh and blood creatures, is problematic. Their integration into any manner of multi-planetary system of human settlements seems unlikely or, at least, open to question. Minimally, we cannot safely assume that this will happen, even at some unknown point in the future. We cannot automatically factor the availability of these places into our assumptions.
Accessible surface, of significant scale, may well come down to the 2% that remains once we discount the gas giants, the surfaces of the inner planets, some of the larger asteroids (such as Ceres and Vesta) and various moons near and far. Of the latter, there is our own Moon (3475km diameter) and there are the Galilean moons of Jupiter, large enough to have been spotted with 17th century telescopic equipment: Io, Ganymede, and Callisto (which are slightly larger), and Europa (which is slightly smaller). There is Saturn's moon Titan (larger), and Neptune's moon Triton (smaller) but averaging out in the same broad territory as the Moon. In addition, there are the dwarf planets and various other bodies, all of which are significantly smaller. The moons themselves are all significantly smaller than the Earth, Mercury, Venus and Mars. In fact, with the exception of Venus, every accessible surface turns out to be much smaller than the Earth. We take up a quarter of the 2%. (An additional reason to regard the Earth as truly remarkable and irreplaceable.)

Given their weaker gravity, and the reduced energy requirements for leaving them (again excepting Venus), it is tempting to think of all these worlds as potential sites for a human presence. However, Io could be too exciting with its volcanoes; Titan has a poisonous atmosphere; Europa has a thick icy crust. All these worlds may be ours, but the 'all' is less than we might once have believed. The bottom line is that there are four good candidate moons in the solar system (the Moon, Ganymede, Callisto and Triton). Mercury and Venus are hellish hot. After the Earth, that leaves just one other unusually suitable planet, i.e. Mars. The rest of the 2% of surface is possible but not nearly so welcoming. Eventually advanced terraforming techniques may make more worlds habitable, but that is too distant a prospect to concern us now. Mars is hard enough. Surface turns out to be a precious and limited potential resource. Of course, it is not only a resource. The solar system is not a giant quarry. But use-as-resource is one aspect of our relation to it.

1.2 Expansion
The background assumption here is, of course, that there is a good rationale for humanity to make use of planetary, lunar, martian and other surfaces, i.e. a rationale for use to go somewhere. This is an assumption which is notoriously difficult to justify in simple terms, or indeed in any terms at all. There seems to be no single clear-cut justification that silences or obviously outweighs all conceivable objections (Schwartz 2017a, 2017b, 2018). Even so, many people do seem to have a strong intuition that space settlement is not just ethically defensible but would constitute progress for humanity, or for life as such. Widespread and sustained intuitions are not always defensible, but they are not easily dismissible. They have a place in initial deliberations even if, at some later point, they may be set aside. This is a familiar methodological point within ethical theory, one associated with the idea of pursuing a 'reflective equilibrium' in which intuitions are allowed to shape overall sets of principles and theories, which then lead us to re-evaluate the plausibility of the particular intuitions (Rawls 1974). Methodologically, something of this sort, with allowances made for qualification and nuances, may be 'the best game in town.'
In line with this methodological assumption, we may say the following: the idea that there may well be a duty to extend our presence, or the presence of life, is a particularly difficult intuition to set aside. This does not mean we have to “be fruitful and multiply” (Genesis 1:28) unthinkingly but the strength and widespread nature of the intuition may well support the case for regarding it as the initial default option. Familiar attempts to claim something more than this have, of course, been tried. Appeals have been made to a variety of different considerations: socio-cultural significance, e.g. it is better to be ‘open’ to expansion than ‘closed’ to what is other (Turner date; Zubrin date); the idea that space settlement can improve our attitude towards the Earth (Garan date, Bezos date); the value of science which requires that we expand our presence (Jim Schwartz has suggested that this is probably the strongest argument, yet still problematic); the importance of backing-up the Earth (Musk date, Hawking date, Rees date); human expansion as a vector for life as such and, in the absence of any certainly about the existence of life elsewhere, we may have a duty to expand life (Dyson date, Milligan date); space offers prospects for utopia (Tsiolkovsky date, various libertarians). Appeals have even been made to political rationale, to the prospect that space offers as a continuation of our liberation from the aristocratic legacy of Europe and that we are economically committed to indefinite expansion rather than to any more stagnant domain (Zubrin date again).

In the more questionable column we should probably place appeals to anything like ‘Manifest Destiny’ or ‘taking what is ours’ with their colonialist overtones, yet such ideas have their supporters (Green 2017). This is not, however, the 19th century. Progress (whatever is may be) is not dominion. Actual colonial projects strike most of us as morally flawed (for good reasons) and, as a basic economic point, the Solar System will not permit indefinite expansion. It is not large enough for this to occur or (as we shall see below) large enough for the dynamics of expansion to be unimportant.

Focusing upon whichever cluster of the above considerations we regard as most plausible, it is tempting to say that none of these reasons seem obviously compelling, but ‘look at the number of them.’ In combination, they align and may possibly add up to something a little more compelling, like a bundle of sticks which are strong enough to do work when joined together. But the jury is still out. Certain kinds of weak justifications do still remain weak in combination. Perhaps a further argument is required about how these reasons might combine. Even so, they certainly seem to match well with the methodologically-driven assumption that some extension of our human presence should be regarded as the default option. And this assumption, in turn, aligns well with the sheer pragmatics of space. Whether we like it or not, humanity is increasing its off-world presence, and it is likely that this will continue. While such expansion could remain restricted to a near-Earth economy, because of the length of time that larger-scale investments would take to yield a return, there is at least one clear rationale for thinking that it will not do so and that broader expansion is the likeliest prospect.

1.3 Location
The rationale is straightforward. The utilisation of space resources on any significant scale will require space mining, and particularly the mining of metallic asteroids. Inconveniently, the number of asteroids that are of the right size and composition and to which we can send suitably massive mining equipment, given our present rocketry, is surprisingly small. Maybe as few as a dozen today but growing to hundreds as we find more and more powerful rockets are developed (Elvis 2014). The SpaceX Falcon Heavy or its prospective replacement, the Big Falcon Rocket or Blue Origin’s New Glenn and/or New Armstrong may bring us closer to this prospect. The obvious solutions to the problem of access are that we should try to shift more of them towards us (technically feasible, given foreseeable future technologies, but difficult and also somewhat dangerous) or that we must go to them. Again, the latter looks like the default. Sustained and large-scale asteroid mining may well require that we extend our human presence out at least as far as the Main Belt asteroids. And that is where Mars enters the picture. If we are ever seriously in a position to engage in Main Belt mining, then we will need an initial base of operations from which to do so. Preferably, one with a good orbit, and also with a far shallower gravity-well than the Earth. Mars looks like the obvious candidate (Taylor, Elvis and McDowell 2018). Indeed, it looks like the only plausible candidate. We could, of course revive the idea of a mobile off-world habitat, an O’Neill cylinder of some kind (O’Neill date). However, quite apart from the safety concerns that this would raise, such a project would only be viable given existing and extensive asteroid-mining operations. It would be a case of putting the vehicle (possibly some analogue of the Titanic, if we move too quickly) before the horse.

What follows from these rough and ready considerations is surprisingly clear. Even if there were no resources of worth on Mars, the pragmatic rationale for establishing some sort of stable human infrastructure and presence looks strong. Mars settlement (of some scale) and any extension of mining to the Main Belt asteroids, may well have to go together.

2 Protection as a Problem of Containment

The genuineness of this pragmatic rationale for establishing a presence on Mars drives us to consider environmental protection for Mars. ‘Environmental protection’ is not, however, ‘planetary protection’ in the current and restricted sense used in space law and policy formation. The latter is presently limited to considerations of avoiding back contamination (returning anything dangerous to Earth) and limiting forward contamination (thereby spoiling sites of scientific interest by accidentally bringing our microbes to them). We will instead refer to “planetary environmental protection” in order to stress our broader concerns.

Planetary environmental protection, as understood for the Earth, involves a range of safeguards for diversity and for unique objects and places so that current and future generations may enjoy and identify with them. Often it goes beyond human concerns alone or, at least, blurs the boundaries between human concerns and concerns that reach beyond the significance of the human. To some extent, this happens with appeals to the integrity of places and things (Milligan 2018). What we will point out, for now, is that insofar as the
arguments for such terrestrial environmental protection draw upon considerations of uniqueness or irreplaceability, variants will also apply to Mars. This will hold irrespective of any further back story is then told about what we mean when we refer to the ‘value’ of anything or our reasons for ‘valuing’ anything, unless the back story happens to deliberately build in special and exclusive claims about our relationship to the Earth. We have no intention of thinning our argument by adding unnecessary premises. When reasons for protection appeal is to uniqueness or irreplaceability *simpliciter*, such appeals will carry over and also apply to Mars.

Mars is, after all, a unique place with a distinctive history. It is not another Earth. The martian terrain, Olympus Mons, the Valles Marineris, and all of the features which go to make it so distinctive, are plausible candidates for safeguarding against destructive use. This uniqueness does not, however, require us to take a hands-off attitude. It does, we argue, mandate that we consider environmental protection of Mars before we act.

One of the reasons why uniqueness does not require a hands-off attitude is that ethical deliberation is not exhausted by pointing out that there are reasons for doing x, or for not doing x. As a point about practical reason, there are often countervailing considerations: reasons which point in different sorts of directions and these are not easily silenced. This leaves moral agents such as ourselves with the difficult task of weighing up multiple interests (including those of *being good agents*, rival obligations and conflicting duties). These may sometimes have to be traded off against one another, simplified and weighed in order to arrive at a decision under conditions of uncertainty. This is what a good deal of our actual experience of ethical agency is like. It is tempting to say that humans are naturally ethical pluralists, responsive to more than one thing at any given time and that this may be a beneficial legacy of our biological history. Alternatively, we can appeal to what goes deep within human socialisation in cultures such as ours. (It is, by definition, an in-built feature of anything like a broadly liberal society.) Any one-dimensional argument for unbridled settlement or hermetic protection is therefore liable to fail because it would require us to be people of a radically different sort. The diametrically opposed view that species expansion trumps all considerations, or the view that humans are a sort of virus from which worlds need to be protected, are both unrealistically monomanical. When it comes to ethics on an interplanetary scale, between worlds, our best response may have to turn upon an account of what good ethical agency and decision-making is like, because nothing is trumps.

In line with this approach, a plausible case for planetary environmental protection in the case of Mars need not be based upon a denial that there are good reasons for wanting to go to Mars, for establishing a stable human presence there, and for using resources *in situ*. There may even (as suggested above) be a duty to go, or to take preparatory steps in that direction, although this is a noticeably stronger claim.

The issue of protection may, then, best be set in the context of an acceptance of both stakeholder interests and planetary integrity. By taking this approach we can acknowledge the legitimacy of competing claims, including the legitimacy of at least some
commercial claims of interest, while doing justice to the idea that it is worthwhile (and is, perhaps, an obligation) to protect the Martian-ness of Mars. And this remains the case even if we acknowledge the unavoidably transformational role of human landings, a sense that, in Erik Conway’s terms, “The Mars scientists want to study won’t exist anymore. Some other Mars will” (Conway 2015 page number). This approach does, however, require that commercial interests are not viewed as, automatically, overriding. And this has a certain policy-aptness. It is in line with the current wave of legislation from Europe and the US which favour the opening of pathways to commercial activity while endorsing the ongoing importance of other considerations (most obviously, those of science and compliance with international law).

Irreversible changes and changes which might affect the integrity of the planet will, accordingly, have a special significance. As an extreme example, any attempt at melting the ice caps in order to thicken the Martian atmosphere would qualify. If we are ever in a position to attempt this, the project should not be evaluated in exclusively technological terms: can will not imply ought. We might then at least consider (as Kim Stanley Robinson does in his Mars trilogy) restricting changes to atmospheric density in order to preserving the original Martian-ness of Olympus Mons and other high-altitude sites. These terraforming examples are, however, far beyond the immediate context of a more modest move towards mining operations in space.

As indicated above, it is our contention that the primary threat to what is worth protecting on Mars may well arise as result of its strategic location. It may be thought of as a problem of containment in two senses. First, ensuring that broader space objectives do not spill over unduly onto the Martian surface (Milligan 2015). Second, constraining the expansion dynamic once surface activities do begin. Up to a point, this first of these considerations makes the protection of Mars contrast with the lunar protection and may even put the two in tension.

For example, one of the Moon’s special resources is Helium 3 (³He), a special target for us in fusion power generation. The prospect of asteroid mining for ³He could relieve pressures upon the lunar surface in favour of processing the asteroid regolith (the powdery surface material) that also contains it. While the density of ³He is less on asteroids than on the Moon (due to the ten or more times lower solar wind flux in the Main Belt) we have fewer reasons for asteroid protection than for lunar protection, especially once the larger asteroids (for which claims of uniqueness and integrity might well be made) are set aside. ³He mining, especially if we can reach the Main Belt could be a viable alternative to lunar mining The Main Belt activity that might relieve pressures towards lunar mining may require at least some associated activity on Mars.

Thinking of matters from the standpoint of containment, both senses involve a significant shift. While the ‘expansion dynamic’ sense can be viewed from a strictly-planetary attitude, the ‘spill-over’ sense requires a shift to a broader context set by growth and development beyond Mars, placing it within the space economy as a whole. Given the limited number surface areas available to us, and the possibilities of irreversible changes on
such surfaces, it makes sense to set planetary-level environmental protection within such a broader context. Approaches to planetary protection, even in our extended ‘environmental protection’ sense, have not always done this. Exceptions here are work on ‘cosmocentric ethics’ (e.g. Lupisella 2016), which may be problematic because it raises concerns about what a viable ethical theory has to look like and how broad our outlook can be, and the more accessible emphasis placed by Chris McKay (date) upon diversity across the Solar System.

The difficulties of situating Martian protection within any kind of broader context are, of course, considerable. Given the limitations of available planetary and other surface for us to work with, it does, however, seem to be the right way to go. Surface is a limited resource. Our favoured pathway for doing so, set out in a more detailed case for treating an extensive portion of the Solar System as ‘wilderness’ (Elvis & Milligan 2018), involves an attempt to establish a large-scale constraint by establishing how much of the accessible Solar System we can safely use without running the risk of some reasonably-proximate generation of humans facing resource exhaustion. (In the specific sense of having an economic system that requires new resources for expansion but having no new resources to draw upon.) In line with our pluralistic approach, this will not be exhaustive of the broader context, but an important part of it, a framing principle.

Below, we briefly outline our framing principle, and then proceed to outline some ways that it might be applied in the case of Mars. The framework is necessarily provisional. It stands in need of fine-tuning. Its application to Mars is also provisional in a further sense: the framework might itself be accepted yet arguments ensue about how best to apply it to any particular planetary surface (or surface of any sort). Up to a point, principle acceptance and principle application are independent. However, the framework for protection as wilderness does seem to have at least one important direct implication (however it is applied in practice): the default for planetary environmental protection on Mars ought to be more robust than the protection of iconic sites such as Olympus Mons or examples of typical terrain e.g. in some system of planetary parks (Cockell and Horneck 2004, 2006). Any plausible system of environmental protection would certainly include these sites. But, if our case holds, the default option could not be restricted to them. There might, of course, be reasons to over-ride the default. Nonetheless, it ought to be the default.

3 The 1/8th Principle
Our driving consideration is that future generations ought not to be faced with a situation in which there is an expansion dynamic that requires new resources, but the resources of the Solar System have been used up and no new ones can be brought into play. Such a situation might be regarded as a ‘Malthusian crisis,’ in the sense that it would be a case of required growth outstripping the materials available. Increasingly marginal resources would have to be brought into play until the point at which no significant new resources were available. For the purposes of the argument, we will assume that the Solar System is a closed system.
For the most part, this is actually true. Very little comes in from the outside in the form of interstellar asteroids and comets (Trilling et al., 2017).

Given a reasonable ethical concern about future generations, the harms made unavoidable by any such Malthusian crisis, are something to avoid. At least, this is the case if the risks of such a crisis are genuine and could not readily be dealt with through some known or predictable mechanism such as a movement of humans out of the system (a possibility set aside at the very start of this paper), or recycling (which would have to exist on a massive scale if we established a stable human presence anywhere else). Of these two, the latter is the most plausible reason for discounting worries about resource exhaustion. However, all recycling systems are imperfect. Their problems of co-ordination and control will tend to grow with scale, or at least they will grow with the mega-scale of resource utilisation and resource-commitment across the Solar System as a whole. For example, if large fractions of the solar system’s resources were ever to be built into structures upon which the large-scale continuation of life depended (e.g. O’Neil habitats) this would commit a large amount of resources at any given time. Everything would remain, in principle replaceable, and available to be recycled, but not all at once. Recycling on its own, consequently, slow down and mitigate the onset and effects of such a crisis, but if a growth dynamic continues unchecked within a sufficiently large space economy, it will not be able to prevent an incremental approach towards a point of “super-exploitation” (Elvis & Milligan 2018). A point where the new resources required, in order to compensate for the imperfections of recycling, cannot be secured.

The only ways to avoid such a crisis are either to avoid growth on the scale that could threaten it, or else to engage in such growth only on the condition that a safe ‘breaking distance,’ is built-in. That is to say, there must be a point beyond which any deliberate expansion ought to be avoided except in emergencies. We should not intentionally move into the breaking space because it is all that is left before harmful impact. By the time such a point is reached (if it ever is) the economic system should already have transitioned to zero or negative growth. If it has not, then the remaining distance should be at least long enough to allow for an emergency transition to occur so that, at the point of new resource exhaustion, any requirement for new resources will have been eliminated or at least minimised. (So that the potential for harm is also minimised.). In such a scenario, we would still be in trouble, but better placed to deal with it. Our estimate is that even for a modern economic system, it would require at least half a century, i.e. 50 years, for such a zero or negative growth transition to occur. This is comparable to the time from the opening of the first commercial AC electric power station in Deptford to widespread use (1881 – 1931), or from the first ARPANET (1969) to today’s internet. Our position, then, is that the limit to deliberate, non-accidental, non-emergency, growth should be at least this far away from the final crunch point, the point of super-exploitation.

Given the immensity of the Solar System, it may seem that any concern of this sort is unnecessary. We will never exhaust the system’s material wealth. However, we humans have encountered such arguments about limitless bounty before. We have seen the film
and do not like the ending. Such claims are similar to those advanced in the 19th century to present the Earth as a place of inexhaustible plenty, a great ship sailing through space, amply supplied with many storage holds that might be opened. When one is exhausted, we might simply move to another. This was, as we now appreciate, somewhat naïve. Strictly, it was naïve at the time (George date). It failed to take into account the exponential nature of economic growth. Modest annual expansion can lead, cumulatively, to massive expansion. Take, for example, the average growth rate in the West over the period since the beginning of the industrial revolution, a little over two centuries ago. This has been around 3.5%. This too seemed modest, and unthreatening. However, an economy growing at 3.5% will double in size every 20 years. After 200 years, it will be a thousand times larger than at the beginning. While we too are ‘at the beginning’ in terms of expansion into space, when we allow for the limited available planetary surface, and other available surface, exponential growth at anything like this rate could easily exhaust the systems immense available resources over the course of a limited number of generations. It could do so within the kind of timescales where the actions of the current generation may have a reasonably predictable effect. Beyond a certain threshold, we will allow that there is no way to tell whether or not the overall long-term impact of what we do now will turn out to be advantageous or disadvantageous for those who come later. An epistemic veil falls over the more remote future.

If the intention, hope (or fear) is that a space economy will reach at least a sustained 3.5% growth rate or anything close to that figure, planetary surface ought to be regarded as a limited resource that could easily be exhausted. Given that Mars accounts for such a large proportion of the available surface, caution is required about the Martian surface.

If there is to be at least a 50-year breaking distance, into which we do not want to deliberately move, then zero or negative growth will have to be achieved while two and a half doubling periods remain before the point of super-exploitation. To allow for a little extra room (budgeting for unforeseen difficulties, in the way that any wise project of construction would do) the minimum may well be closer to three doubling periods, totalling 60 years. Adopting this ‘tripwire’ means that no more than 1/8th of the Solar System’s total resources ought to be brought into use. After all, doubling from this point would pass successively through a quarter, half and 100% usage, over only three doubling periods, again at a growth rate of only 3.5%. A higher average growth rate would mean than more doubling periods would need to be added to allow for the half-century emergency slowdown. A lower average growth rate would mean that fewer doubling periods might be required. At present, and given the historical precedent cited, the latter option seems unlikely. However, any requirement to call upon successively more marginal resources might result in a natural slowdown as the economic system grows large and unwieldy. Even on Earth, it is not obvious that the average pace of expansion from the industrial revolution until recent times can be indefinitely sustained.

The assumed figure of around 3.5% growth therefore seems like a reasonable baseline to work from. (With allowances for adjustments at a later date.) In line with this
baseline, we have suggested elsewhere that the adoption of a ‘1/8th principle’ formulated as follows: “While economic growth remains exponential, we should regard as ours to use no more than one-eighth of the exploitable materials of the Solar System. And by ‘ours’ we mean humanity’s as a whole, rather than any particular generation of humans or group of generations. The remaining seven-eighths of the exploitable Solar System should be left as space wilderness” (Elvis & Milligan 2018).

There are, of course, all sorts of workable problems that flow from this position. We might, for example ask ‘1/8th of what?’ Above, we have focused primarily upon surface area, but the principle applies more generally to mass, volume and resource type. Given that our concern is pragmatic, and that the distribution of resources across the Solar System is extremely uneven (thankfully so, otherwise none of us would be here) it seems best to go sectoral over the issue of measurement and make several allowances in order to respond to the measurement problem. Two of the most obvious are allowances for (i) local variations in how resource-utilisation is measured; and (ii) trade-offs within and between sectors, irrespective of how the lines between them are drawn. The first of these provisions will still allow for a reasonable overall summation of resource-use across multiple sectors to occur. There is, in other words, no ‘in principle’ measurement problem, but only a series of smaller problems concerning what the best local measure is going to be in any given case. 15% utilisation by the local unit of measurement in one sector and 5% utilisation, by a different local standard in another sector, will still sum to an overall average of 10%. In the case of planets, such as Mars, surface area looks like a good default for the standard measure, with the interior surface of lava tubes perhaps counting multiply, or else considered not as surface but as a sector in their own right. In the case of Main Belt asteroids, mass or, better still, mass for each asteroid type, may be more appropriate. A summation across the two may still be made.

The second provision, for trade-offs comparable to those for carbon emissions on Earth, will allow for a reasonable flexibility. We acknowledge the imperfections of process associated with terrestrial emission-trading, however, imperfections are rarely good grounds for abandonment of a process in the absence of a politically realisable alternative. In the case of Mars, while the default would be one-eighth utilisation, its unique significance could lead us to allow legitimate trade-offs against resources elsewhere. (Just so long as any other planetary environmental protection constraints were met.) Nonetheless, the default option or starting point, should be the reserving of 7/8ths of the planetary surface. This remains so even if we think it likely, or even obvious, that more than 1/8th of the Martian surface is ultimately likely to be brought into use, at some point in time as a result of political or economic pressures. (Or both.) One eighth of the Martian surface would be around 18 million square kilometres i.e. roughly the same size as South America.

I. Containment Problems in the Case of Mars
Should the one-eighth principle be applied only at some later point in the process of economic development in space, rather than from the start of mining processes, or at the point when we begin to transform the surface of Mars in non-trivial ways? Assuming, as before, that surface area will be the standard planetary unit of measurement and allowing that Mars accounts for a significant proportion of it, there is a clear case for saying that the clock should already be ‘on’ when we begin transformations of the latter sort, if not before. The line between trivial and non-trivial will, of course, be disputed, and there may be borderline cases. But there will also be clear-cut cases: the presence of a lander or rover, on its own, would not count. Strip mining for habitat insulation material would do so.

This contrasts with the situation on our home planet, where a variety of social and economic considerations would make any current terrestrial appeal to such a limit difficult to apply. Even the oceans, which cover just over 70% of the Earth’s surface, have been significantly modified by our human presence (Jones et al., 2018). But here, on Earth, we are in medias res, whereas with Mars we begin with more of a blank slate. And while the utopian dreams of Konstantin Tsoilkovsky for a new and perfect world in space may be a poor guide to what is possible, the admonitions of Ecclesiastes are likely to be just as misleading: there can be new things under the Sun. The assumption that we will simply repeat the same old patterns of environmental misuse is not a safe assumption. (It separates humans from their relation to history and place.) Because Mars is not another Earth, our human relation to it cannot actually be the same. The differences between Mars and the Earth do, however, raise the question of whether or not the planetary surface of the Earth should itself be part of the total surface area of the Solar System that is taken into account for measurement purposes, especially given the even larger proportion of total available surface area that the Earth takes up. Put in other terms: ‘Is the clock already running, now, even before any human has gone to Mars?’

Viewing the Earth in the same larger context that we have viewed Mars, may incline us to say ‘yes.’ This is how we have run the position above. However, a one-eighth principle could be run with an Earth-excluding approach to measurement, starting with near-Earth asteroid mining or significant human activity on Mars, but no later, i.e. at the earliest point when it can be applied. We say this as a reaffirmation of a concession made at the start: there are a range of options for measurement, but these are independent of the case for the one-eighth principle. They open up further lines for research and reasonable disagreement.

Given that the clock should then be ‘on,’ how should the one-eighth principle actually be applied to Mars, when the 1/8 principle is formulated in the terms above or in proximate terms? Here, as multiple approaches are possible, we can afford to be a little more speculative than we have been above and supply, on the one hand, clues, hints and pointers and, on the other, a cautionary note about perverse application of the 1/8 principle. Minimally, on any plausible approach to its application, the principle does point towards the need for a more robust approach than protection via planetary parks alone would allow, even if adopted as a way of protecting special or unique sites such as Olympus.
Mons, or typical areas such as some of the cliffs with seasonal outflows that may be water and so may host life (McEwen et al., 2011) or perhaps the water-shaped Ma’adim Vallis channel. The 1/8 principle is not in any way at odds with the protection of these things, or with the need for planetary parks on Mars. It is not. Both would, no doubt, figure in any sufficiently robust planetary environmental protection policy. However, on its own, protection of this sort would allow a much larger proportion of Mars to be brought into use without requiring the introduction of any compensating restrictions elsewhere.

This is not, of course, what the planetary parks proposal was intended to do. It identified a minimal form of environmental protection rather than an upper limit. Treating it as the latter would be a perverse application of the proposal, deploying it as a way of pressing the claims of “entitlement to use” rather than of “duties to protect”. Safeguards may be required in order to avoid any similarly perverse application of the one eighth principle, especially in the light of the introduction of a counterpart to carbon-emissions trading. As the 1/8 principle is concerned with a system-level problem of expansion in the face of limited resources, it could be used to over-ride local protection duties, unless suitably constrained. It can do good work, but on its own, it cannot do all of the required work.

This can be seen more clearly if we look at the specific case of applying the 1/8 principle to Mars. There certainly could be long-term pressures to use more than one-eighth of the planetary surface, and the emergence of such pressures might be beyond anyone’s control. Trade-offs would then be required in order to comply with the principle. But what should such trade-offs look like? It may be tempting to fill in the detail by appeal to some metaphysically deep consideration about the inherent value of some objects and places, and the lack of any such value in other cases, which would then be more suitable for use. The principle could be shaped in line with such arguments, and they do have their place. They can help to bring considerations of a deep sort into discussions when appeal to instrumental and pragmatic reasons for protection might miss something important. However, theories of value are unlikely to command the kind of breadth of support that actual policy in a democratic society needs to be effective. They figure more in precursor discussions rather than anything akin to policy discussions. And while the analysis here is not exactly of a sort that could be directly adopted as policy (few scholarly arguments are like that), it is at least a little closer to being ‘policy apt.’

Accordingly, as made clear from the beginning, we will use the human practice of treating objects and places as consideration-worthy in their own right, rather than as having ‘value’ which would require a deeper metaphysical back-story. Given this, and given that we have already adopted a multi-generational perspective appealing to the interests of future generations, it will make sense to prioritise not only the kind of objects and structures that we value, but also those that future generations are likely to value or even, in the case of settlers, to regard as bound into their identity. The Valles and Olympus Mons are obvious candidates. They are striking features of the Martian landscape with potential for a
connection to identity at least as much as Mt. Rushmore, the Grand Canyon, Uluru, the Great Barrier Reef and the Amazon Rainforest are bound into terrestrial identities.

Less obviously, there are the lava tubes associated with the Martian shield volcanoes, tubes such as those near to Pavonis Mons, or the ‘seven sisters’, i.e. the caves feeding into the side of Arsia Mons. The mention of lava tubes in this context of a robust protection policy is, however, likely to meet some push-back. They are a key strategic resource on Mars. They may even be thought of as the key strategic Martian resource, the closest resource equivalent to the Peaks of Eternal Light on the Moon [REF - EMK], albeit for different reasons. While the Peaks are important because of their combination of volatiles and near-constant exposure to the Sun, the Martian lava tubes are important because of the likely presence of volatiles and, more crucially, their shielding from Solar radiation that will make them prime settlement sites [REF].

Lava tubes may, in fact, turn out to be so rare and so useful for early phases of human habitation (on whatever scale) that anything other than near-full use would be unthinkable given a sufficiently large human presence. At the very least, they merit inclusion in ‘planetary park’ protection for a typical sample of what is likely to be lost elsewhere, so that future generations can enjoy the tubes in more or less a condition of wilderness. In terms of a more robust system of environmental protection in line with the one-eighth principle and with an allowance for trading, tubes would almost certainly be worth counting in a weighted manner as double, triple or greater their surface area, rather than something that might be traded-off against greater restrictions upon comparably extensive areas of the Martian surface.

The point may also be generalised to other special and scarce resources on Mars and elsewhere: trading allowances on their own will offer inadequate protection if we want to protect all that humans are likely to value and identify with. Protection will be more effective if other side-constraints and/or a system of weighting is involved. But, in order for this to work, and as a disincentive to the repetition of terrestrial mistakes, the trading cost of using lava tubes would have to rise incrementally once we move beyond an eighth, and the trading costs of using tubes to the point where pressure is placed upon the final protected examples, would have to be prohibitively high. Only considerations of the most serious sort (such as the avoidance of tragedy) should then lead us to risk their survival in a reasonably pristine condition. Without weighting, and side-constraining, trade-offs could be indulged in too easily and the one-eighth principle could merely be used to give an ethical veneer to rapacious over-use of protection-worthy sites.

Nor are the lava tubes the only sites of the latter sort, where special provision would be required in order to avoid perverse applications of the principle. Phobos and Deimos also look like good candidates for weighted protection. As with the larger asteroids such as Ceres and Vesta, they are plausible candidates for treatment as objects with integrity. At the same time, they are also systemically integrated with Mars in a way that would be salient to the identity of any future human inhabitants. There may even be a case for intervention in order to stabilise their orbits should they erode dangerously, or if problems of fragmentation
threaten. The same cannot, however, be said of *everywhere*. Inaccessibility may be an issue. Because of their inaccessibility, particular regions may never feed quite so directly into Martian identity so strongly. The poles may not be as inaccessible but their extent has also varied significantly over time, and this too may affect the ways in which protection might be effected (as well as the justifications offered).

[Martin NOTE to incorporate Well, their extent changes seasonally and millions of years ago Mars had a different tilt to its orbit, so they may not have existed then and are relatively new features compared with the age of the planet. That doesn’t seem to make them unworthy of some protection to me though.]

Given this, there is nothing about a dramatic reduction in their scale that would be obviously out of keeping with the integrity of Mars or with a human sense of the latter. Their case for special weighting is probably much weaker. Constraints upon use, e.g. to enrich the Martian atmosphere, should perhaps be of a different sort (e.g. we should not over-reach beyond the availability of reliable technology for any attempted atmospheric enrichment).

Under the 1/8 approach envisaged here, the use of Martian resources may not simply be traded off against each other. Mars need not be a closed system. Bulk imports from the Main Belt are conceivable. Martian resources may also be traded-off against resources elsewhere (with suitable weighting). And, the greater the trade-offs between utilisation of Martian resources and of resources elsewhere (e.g. in the Main Belt), the stronger the case may be for using access to both as a stepping stone to the Kuiper Belt, access to which could then legitimate a greater use of a ten times larger amount of resources than in the inner of the Solar System (Gladman et al. 2001), without automatically violating a one-eighth principle. The bigger the pool of accessible resources, the bigger the one-eighth will be.

Even with an assumption that we *may* ultimately access the Kuiper Belt, caution is required to avoid too many trade-offs between *distinctive* sites in the inner Solar System, near to Earth, and larger amounts of more *mundane* asteroid materials elsewhere, in either of the belts. Such an application of the principle truly would be perverse, in the sense of legitimating an indefinite postponement of environmental protection and licensing the short-term destruction of the most obviously protection-worthy locations just so long as promises of large-scale future constraint are made. This is not our intention. It is better that good principles are in place, rather than principles of any other sort. However, good principles may be applied badly and there is ultimately no safeguard against the latter beyond the safeguards of culture (political, ethical, social). There is no clever way to render any principle ‘self-protecting’ against misuse. What we can do is indicate that the proper application of the principle should bear in mind its driving rationale as a protection measure: the avoidance of runaway economic development and not its legitimization.

5 Conclusions

*Notes for conclusions:*
1. Mars is a unique place in the solar system for humans.
2. Mars’ resources are finite, though large.
3. protection of Mars’ resources goes beyond traditional “planetary protection” to “planetary environmental protection”.
4. exponential growth goes from minor use to full exploitation rapidly.
5. we should consider environmental protection before we start using Mars’ resources.
6. the 1/8 principle is a prudent boundary and organizing idea.
7. 1/8 principle is relatively easy to turn into policy choices.
8. the 1/8 principle can be applied to sub-categories and then aggregated using weighting schemes.
9. like all principles this one can be used perversely, but nonetheless it sets up and frames the necessary discussion.

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