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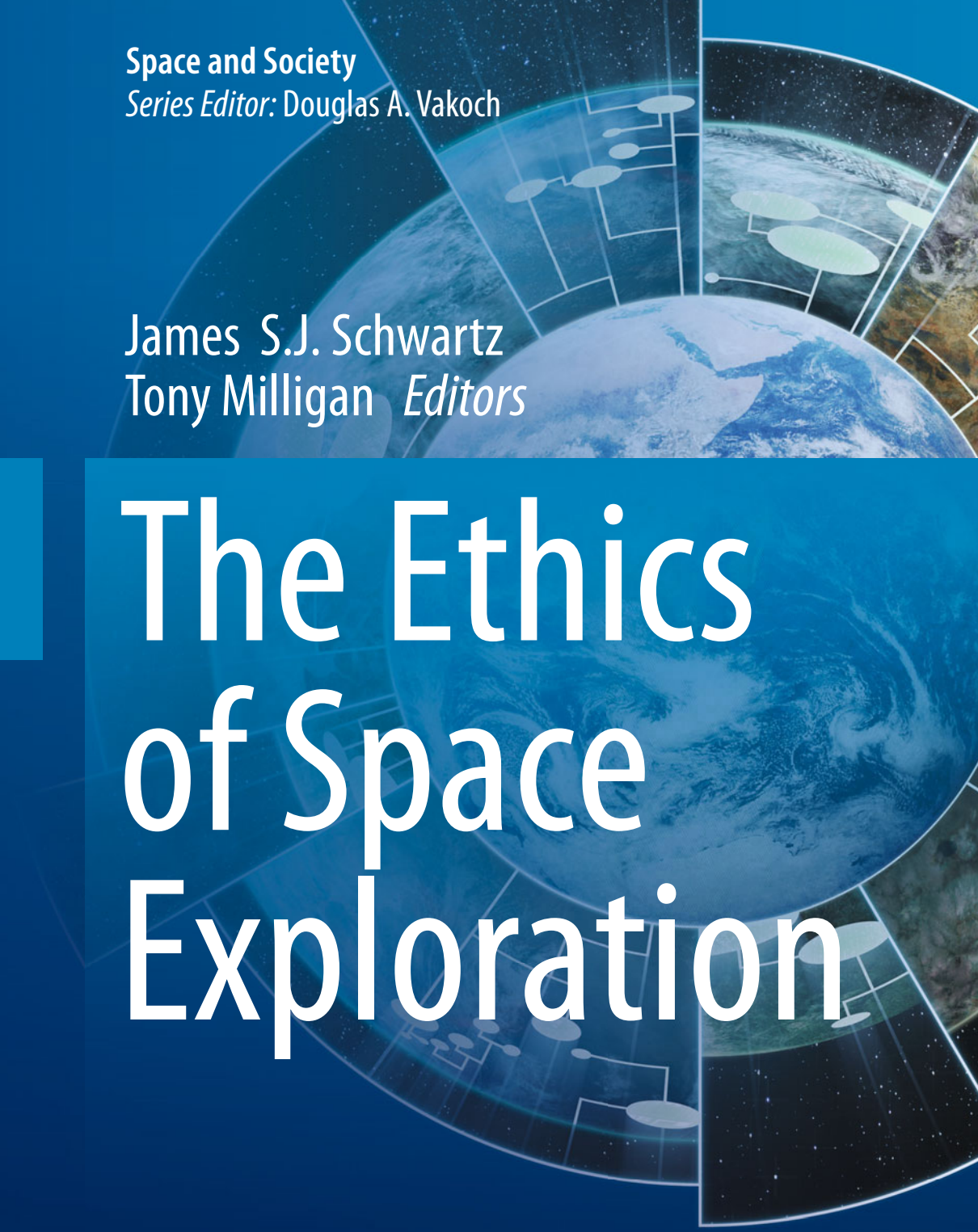
The Ethics of Space Exploration



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The Ethics of Space Exploration

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For Ian M. Banks, falling always outside the normal moral constraints.

Contents

Chapter 1
Introduction: The Scope and Content of Space Ethics

James S.J. Schwartz and Tony Milligan

1.1 The Purview of Space Ethics

Space ethics epitomizes inter-disciplinarity. Its contributors range from astrobiologists to science fiction authors, from geologists to philosophers, from lawyers to political scientists; and from engineers to planetary scientists. It should come as no surprise, then, that space ethics as a field of inquiry resists a simple, unified description. Rather, it is comprised of a broad spectrum of issues and questions that draw on equally diverse intellectual resources.

On the more "theoretical" side of this spectrum are characteristically normative- and meta-ethical questions, i.e., questions related to the construction, standing and evaluation of ethical *theories*: Does the space environment (including the solar system and beyond) contain anything of inherent value (i.e., anything that is valuable for its own sake)?[1] Or is space a mere instrument available for the satisfaction our preferences? What is the moral status of our relationships to various aspects of the space environment—e.g., do we have an ethical obligation to respect

[1]The editors have favored 'inherent' value, in line with a familiar distinction in analytic ethics between 'inherent value' (possessed by that which is of value in its own right) and 'intrinsic value' (possessed by that which is of value to a sentient being without consideration of any further advantage). However, given that these terms are often used synonymously, particularly when ethicists and scientists collide, this favoring of 'inherent' has not been enforced by editorial fiat throughout the volume. Contributors have been left to deploy their preferred terminology.

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or constrain our activities on entities such as asteroids, comets, moons, or planets? If extraterrestrial life (including microbial life) is discovered, would it fall under the scope of moral consideration? And if so, in what way? And for what reasons? And to what degree? In short, how should the consideration of the space environment impact upon the way in which we *reason* about *what to do* and about *what matters*?

Meanwhile, on the more "practical" side of the spectrum, there are a variety of questions about the ethical evaluation of existing and proposed activities in space:

1. Can national and global expenditures on space exploration be justified? Is existing support adequate, insufficient, or superfluous? How should this support be divided between human and robotic exploration?
2. What are the risks associated with various forms of space travel, including long-duration spaceflight? Are space travel participants given adequate information about these risks, and is their assessment of them sufficiently objective?
3. To what extent should we preserve pristine space environments, such as asteroids or planetary surfaces? Are sites potentially home to extraterrestrial life (or traces of past life) more worthy of preservation? How diligently must we work to avoid contaminating extraterrestrial sites with terrestrial microbes, some of which might survive long periods of exposure to vacuum? Why is any preservation warranted in the first place—to protect opportunities for scientific research? Or because, e.g., asteroids or planetary surfaces, or extraterrestrial life forms, are inherently valuable and hence worth preserving for their own sake?
4. What is the most fair and effective way to regulate particularly "popular" locations in space, e.g., low-Earth orbit (LEO) and geostationary orbit (GEO)? Orbital slots in LEO are particularly useful for Earth observation satellites, and LEO is the dominant milieu of human spaceflight. Meanwhile, GEO is particularly useful for global telecommunication satellites. Should access to positions in Earth orbit be permitted on a first-come, first-served basis, or should access to Earth orbit be subject to some kind of social justice constraint?
5. Debris from nearly 60 years of activity in space poses an increasing hazard to both human and remote operations in Earth orbit. What responsibilities do we have to limit the production of this debris? Are we obliged to "clean up" this debris if we can develop the requisite capabilities?
6. Should property rights be granted to those interested in developing space resources, e.g., to corporations such as Planetary Resources, which are interested in extracting mineral resources from asteroids? Should the granting of these rights be made on a basis of first-come, first-served, or should there be an equitable sharing of the resources from space? Would it ever be permissible to terraform a planet, i.e., to use geophysical engineering to turn a previously uninhabitable planet into one that is suitable for human settlement?
7. What kinds of challenges will denizens of space colonies and settlements face? What form of governance or social organization would maximize colonists' security and their personal liberty in an *extremely hostile* environment where basic resources, such as water and air, must be *manufactured?*

As the reader will see, most of these questions—"theoretical" and "practical" alike—are treated in the contributions to this volume. And for a variety of answers to them we point you to the subsequent chapters.

What we wish to emphasize at present is that none of the above questions fall under the exclusive remit of any one scientific, or philosophical (or other liberal arts) discipline. For instance, the "theoretical" task of constructing an ethical theory for conduct in space should draw not only on discussions in philosophy (viz., normative ethics), it should also draw on the space sciences—astrobiology, astronomy, planetary science, etc. After all, an adequate ethic for space should be designed with some minimal account of what the space environment is comprised of. Similarly for the specific question of the moral status of extraterrestrial life, which implicates not only astrobiology and normative ethics, but also chemistry and biology in the sciences, and in philosophy, bioethics, environmental ethics, philosophy of science, and the philosophy of language.

Regarding the more characteristically "practical" questions, resolving those identified in (1) relies critically on the space and social sciences. The space sciences for limning the possibilities of exploration and the expansion of scientific knowledge; the social sciences (anthropology; economics; philosophy; sociology) for assessing and predicting how the course of space exploration will impact upon society. After all, the value of scientific research more generally, and space research in particular, is not often self-evident—its manifestation requires a *human* perspective. Detailing the risks implicated in (2) requires extensive biological and medical knowledge about the effects of reduced- and micro-gravity environments on living organisms. Thus any ethical assessment of the risks posed to space travel participants would not only be an exercise in bioethics and business ethics, but also an exercise in the life sciences. In addition to many of the disciplines already mentioned, the questions identified in (3)–(6) pertain to the law and regulation of space, and thus call on counsel from space lawyers and policymakers. And finally, the task of how to maximize liberty and security in space settlements (7) raises questions of interest to engineers, political philosophers, political scientists, psychologists, and sociologists.

Neither our list of 'big questions' nor our list of relevant disciplines is meant to be exhaustive, but we hope that the reader is left with the impression that space ethics presents a unique and engaging setting for the fruitful interchange of ideas from a diverse array of scientific and liberal arts perspectives. To this end, the contributions to the volume are accessible and state-of-the-art overviews of several of the major issues in space ethics, and should provide readers with an authoritative introduction to the key issues in the field. However, since a history of space ethics is not the particular subject matter of any contribution, we find it helpful here to provide a brief overview of the development of space ethics as it pertains (broadly) to the contributions to this volume.

1.2 Formation of the Discourse

Space ethics, understood in the above sense (and rather like the space program itself) experienced something of a false start with a handful of early publications in the late 1970s and 1980s, primarily as an offshoot of the growth in environmental ethics and with key contributors drawn from the latter (notably, Holmes Rolston and J. Baird Callicott, but work by Wendell Berry and James Lovelock also had some clear ethical dimensions). The most important of these early contributions appeared in Eugene Hargrove (ed.) *Beyond Spaceship Earth*: *Environmental Ethics and the Solar System* (1986) which, although tentative, exploratory and of uneven quality, still remains an important reference point on questions of inherent value and the permissibility of terraforming. An ongoing feed-in from environmental ethics remains clear in several contributions to the present volume, and the debates covered in the Hargrove collection have continued intermittently, through 'outlier' articles about terraforming in philosophical ethics journals and collections, although these matters remain situated at some distance from the policy agenda and from the main debates in philosophical ethics (for example, McKay and Davis 1989 and McKay 1990).

While in many respects a disadvantage, the distance from policy during the early formative stages of the discourse has sometimes had its compensations. Most notably, the work on space ethics that finally began to emerge as part of a more cohesive discourse from around 1999 onwards, was not excessively concerned with the immediate priorities of the Shuttle Program which might have produced an interestingly different sort of space ethics geared towards other priorities such as engineering-related risk, resource prioritization and the character required of pioneering space agents (Pinkus et al. 1997). Instead, these considerations appear in this volume as part of a broader cluster of issues. Nor has the discourse succumbed to the remoteness from lived ethical experience, which, from time to time, has afflicted contemporary philosophical ethics making it difficult for the latter to establish pathways towards research impact. Instead, the contemporary discipline of space ethics has been shaped by two dominant, lines of discussion both of which have at least some institutional connections to NASA and the European Space Agency: one which was opened up in the US at the end of the 1990s following on from the rapid growth of astrobiology and exploring the ethical issues raised by the latter and its connection to broader societal issues, and another which was opened up in Europe, at much the same time, on areas where ethics, policy and space law intersect (the most obvious of these being matters of commercialization, the distribution of opportunities and responsibilities in nearby regions of space) as well as the rationale for space exploration.

The astrobiology and society discussion, as a serious output-oriented affair, began at a workshop on the Societal Aspects of Astrobiology held at the Ames Research Centre in 1999 and a AAAS workshop in Washington in 2003, culminating a decade later in the first major contemporary volume dealing with space ethics, Constance Bertka (ed.) *Exploring the Origin*, *Extent and Future of Life*:

Philosophical, *Ethical and Theological Perspectives* (2009), together with a proposed "Roadmap of Societal Issues," drafted at a workshop hosted at the SETI Institute (Rummel et al. 2012). The roadmap mimicked (and also picked up on the endorsement of social and ethical issues) in NASA's 'Astrobiology Roadmap' (Des Marias et al. 2008) but never quite secured the institutional support given by NASA to the latter, for understandable reasons. Even so, it set a pattern for the inclusion of ethical matters with the search for life and debate about its possible value. The five roadmap goals were formulated in terms which were, from the outset, ethical-friendly:

> (A) Explore the range and "complexity" of societal issues related to how life begins and evolves.
> (B) Understand how astrobiology research relates to questions about the significance and meaning of life.
> (C) Explore the relationships of humans with life and environments on Earth.
> (D) Explore the potential relationships of humans with "other" worlds and types of life.
> (E) Consider life's collective future—for humans and other life, on Earth and beyond.
> (Rummel et al. 2012, p.959)

One notable feature of this US side of the discussion, from its beginnings as an offshoot of astrobiology, has been the interest in societal impact consistently shown on matters of religious commitment. This has carried over into the most recent edited volume on the area edited by Chris Impey, Anna H. Spitz, and William Stoeger, *Encountering Life in the Universe*: *Ethical Foundations and Social Implications of Astrobiology* (2013), and into NASA-funded research work at the Princeton Centre for Theological Inquiry.

The European discussion has emerged partly out of the drafting of the Pompidou Report *The Ethics of Space Policy* (2000) presenting the outcome of meetings and discussions by a joint UNESCO/European Space Agency working group on the "Ethics of Outer Space" held over the previous 2 years. Its tone and content were very different from the US discussion, with an opening declaration that 'Earth and Space are not ours. They are treasures, real and symbolic, which we owe to ourselves to safeguard for our descendants.' (Pompidou 2000, ii). Jacques Arnould, one of the key contributors to the report (and to the volume here), then produced the first systematic exposition of issues in the field the following year, in *La Seconde Chance d'Icare* (2001), which appeared, translated and expanded, as *Icarus' Second Chance*: *The Basis and Perspectives of Space Ethics* (2011), arguing that the most appropriate form of frontier ethic for space was a form of humanism. (In the sense of an ethic that places human identity at its heart, rather than in the sense of something that requires anthropocentric judgements about the value of the non-human.)

With the emergence of these two interweaving discussions, the discipline can now reasonably claim to have arrived at a stage of early consolidation, a point where key lines of argument and dispute have become clear: some contributors argue that everything 'out there' is open to our appropriation, others urge caution out of a sense that humans matter but we are not all that matters. Others urge caution for the sake of humans and because access to space and all it holds is

unevenly (and perhaps unfairly) distributed. Whatever position is taken on these questions, since the publication of the Roadmap and the Pompidou Report, the field has attracted a growing body of academics based in the disciplines of philosophy, the philosophies of biology and science, geoethics (where geology and ethics collide), astrobiology, anthropology and space law. What has marked the field during this phase of consolidation is a combination of two things: a high level of interdisciplinary integration spanning the humanities and relevant disciplines of science, and some tentative degree of institutional connectedness in terms of links with NASA, the European Space Agency and bodies such as COSPAR (the Committee on Space Research established back in the 1950s after the launch of Sputnik and a major player in the discussions on policy and space law).

Where we find ourselves today is also at something of a crossroads with NASA issuing a new *NASA Astrobiology Strategy* (2015) document to replace its earlier "Astrobiology Roadmap," removing much of the societal content of the latter, with the role of ethics still acknowledged but pushed into the margins, consigned to a single paragraph in a document almost exclusively given over to science conceived of in terms which are functional to the discovery of life (Hayes 2015, p. 159). This too is understandable for all sorts of reasons. There is a reasonable concern that ethics may be a source of unhelpful constraints which could stand in the way of the emerging space economy and (on a less commercial note) there is a widespread view that we may now have a good idea of where to look for and discover life elsewhere in the Solar System if there is any to be found. Astrobiology is, to some extent, gearing up for a possible first discovery and all sorts of add-on issues have tended to be pushed into the long grass in order to concentrate upon what is (appropriately or otherwise) deemed to be the central task. Paradoxically, space ethics has been pushed out to the margins at a time when (with the prospect of possible discovery and the emergence of a space economy) it has matured to the point of being able to contribute significantly to the discussion on human activity in space and at a time when its contribution on the ways in which we may legitimately explore may be particularly salient.

There are also various institutional counter-trends which put ethics much closer to the heart of this discussion. While the *NASA Astrobiology Strategy* (2015) turned away from ethics, there has been a marked strengthening of the interest in ethics on the European side with an initiative to establish a European Institute of Astrobiology broadly along the lines of the earlier 'Roadmap of Societal Issues' amid a growing sense of positioning or preparing for discovery, if there is microbial life out there. And NASA too has become involved in the funding of research on the societal impact of astrobiology through Princeton's Centre for Theological Inquiry, again taking the route of ethico-theological reflection on what it would mean to discover life (of any sort) elsewhere in the universe. It seems that these are matters which simply cannot be sent permanently into exile. And the quality of the ethical deliberation itself has improved dramatically from its earliest tentative beginnings, with the Impey, Spitz and Stoeger volume appearing in 2013; a special edition of the journal *Space Policy* on ethics appearing in 2014; a volume edited by Jai Galliot (2015); and a series of three volumes issued by Springer and edited by

Charles Cockell (2015a, b, 2016) on the politics of space settlement and the ethico-political theme of liberty. On the side of monographs, a short book by one of the editors, Tony Milligan, *Nobody Owns the Moon*: *The Ethics of Space Exploitation* was released in 2015 and further monographs by Gonzalo Munévar and Mark Lupisella (also contributors to the present volume) are anticipated shortly. The discourse has already reached the 'usual suspects' stage at which any volume or special edition of a journal is expected to contain articles by some subset of established key contributors, and the present volume certainly has those. But it has also been our aim to reflect the fact that space ethics is a growing discipline with new voices, and multiple dialogues going on at one and the same time. A balance has therefore been struck, or at least aimed at.

1.3 An Overview of the Volume

The papers gathered here try to shed light on many of the key established areas as well as exploring some new lines of analysis. The opening section sets the scene by placing space ethics in the context of human history, deep imperatives and culture. The lead paper, from the well-known science fiction author Stephen Baxter, looks at responses in science fiction to Gerard O'Neil's influential text (1976), an ecologically-driven proposal to deal with energy and population problems through the construction of mass habitats in free space. Baxter's critical assessment of these surprisingly detailed and cogent literary responses to O'Neil considers not only the multiple impracticalities of the initial proposal but also the fundamental imperatives behind mankind's growth and the desire to reach outwards. In Chap. 3 Gonzalo Munévar flips over and, instead, interrogates O'Neill's environmentalist critics in an attempt to renew the vision of artificial worlds offered by the latter, without the initial design difficulties and with underpinnings from evolutionary biology and an appeal to survival concerns in the face of extinction threats.

In Chap. 4 on 'Agonal Conflict and Space Exploration' Eleni Panagiotarakou shifts the theme toward the competitive dimension of space exploration and the ways in which the Cold War tensions between the USSR and the USA, from which the space program can be seen to parallel the ancient *agon*, a rivalry in which the enemy is to be surpassed in excellence but not destroyed. For Panagiotarakou, in the aftermath of the USA/USSR conflict, what has emerged on the USA side is not harmony but a problematic tension of a different sort, one between NASA and the private sector. Struggle of a different sort figures prominently in Chap. 5 where Chris Yorke explores Frederick Turner's 'Frontier Thesis' that the character of a people is determined by the severity of the obstacles which they face. The claim is that without the rigors of a frontier experience human culture is liable not to

consolidate but to stagnate. Yorke upholds the 'frontierist' position against the 'consolidationist' position and argues that human culture on Earth will ultimately depend upon our exploring the utopian potential of space.

Shifting from the historical and cultural context directly to the link-up between space and hard core ethical theory, Mark Lupisella's contribution in Chap. 6 considers the case for a 'cosmological ethic' which stresses connectedness and relationality as a grounding for talk about inherent value. This draws upon a proposal for a special cosmological or 'cosmocentric' resetting of ethics that has been around continuously from the opening discussions in the 1980s but whose content has always been difficult to pin down. Lupisella gives an overview of how his forthcoming book on space ethics attempts to tackle the problem. In Chap. 7 Schwartz picks up on the value theme and challenges the idea that we know enough about the space environment to say for sure just what is and is not of value. An attempt to fix this prematurely may cut us of from novel reasons for planetary protection that might otherwise appear. Shifting the weight of assessment towards character, an option found instead in virtue ethical approaches (and aligned approaches, such as those of Yorke and Milligan), also does not avoid the problems that arise from this epistemic shortfall and raises the classic virtue ethical problem of being insufficiently guiding in our actions and choices. By contrast, Seth Baum's contribution in Chap. 8 adopts a firmly consequentialist approach to matters and sets out to explain why measures to deal with global risk may be more important than maximizing goods elsewhere. Baum also explores the possibility that a strict consequentialism might lead us to prioritize the interests of a more advanced species rather than those of humans (and the possible implications that this line of thought may have for our current treatment of terrestrial non-humans). In Chap. 9, Milligan reaffirms Schwartz's more pluralist approach with a similar precautionary resistance to any attempted foreclosing of deliberation about the kind of ethic that might be appropriate to sustained life in space. He attempts to strengthen this caution through a rejection of any idea that we should be trying to establish an unchanging set of foundations for space ethics (irrespective of whether these foundations are thought of in consequentialist terms or in some rival terms). The claim is that while some rudimentary side-constraints concerning certain sorts of harm may always be in place, they are too slight to perform this task. In short: the right kind of ethic for terrestrial life and even for early settlement might not be the right ethic for everywhere and at all times although every ethic will contain at least some important (non-foundational) features in common. What kind of ethic might then fit remote contexts is something that we are poorly placed to judge. (As with Schwartz, epistemic disadvantage plays a role.)

Chapters 10 and 11 shift us into two contrasting discussions about the nature of our humanity: the formation of our *way of being;* and how space exploration and expansion may impact upon identity. For Francesca Ferrando, in 'Why Space Exploration must be Posthuman,' space calls upon us to simultaneously move beyond consequentialist technologically-focused perspectives and beyond conceptions of the human. For Jacques Arnould, in 'An Urgent Need to Explore,' space

opens up new and undogmatic ways of being and conceiving of the human with exploration itself taken to be a necessary part of human existence. (Here, Arnould picks up on a familiar claim about an imperative to explore, introduced in Baxter's and Munévar's chapters and appearing elsewhere in the volume.)

Chapters 12–15 deal with the contested areas of value theory and the non-human, looking at the issues of planetary protection and microbial value and opening with a paper by Charles Cockell, the leading exponent of inherent or non-instrumental value of extraterrestrial microbes. Cockell argues that although the protection of individual microscopic organisms is impractical in the course of planetary exploration, we can nonetheless develop an ethic of respect for communities of microscopic life, valuing them for more than the uses to which we put them, and avoiding the wanton destruction of other life and biospheres in the pursuit of our own objectives. In Chap. 13 Anna Frammartino Wilks returns to the theme of value and 'cosmocentric ethics' of the sort explored by Lupisella and attempts to give foundations for the latter by appeal to Kant's distinction between *self-organizing* beings (life forms) and *self-legislating* beings (moral agents) as a non-arbitrary basis for claims about value. More specifically, Wilks argues for a '*weak* cosmocentric ethic,' *cosmocentric* in the sense that it acknowledges the priority of interest claims for all valuable beings, *weak* in the sense that it does not attribute inherent value to the universe itself, over and above the beings within it.

Chapter 14 returns to the issue of inherent value with a critique of the latter by Kelly C. Smith. In 'Why Microbes lack Inherent Value,' Smith develops and expands a position that he first advanced in the Constance Bertka volume by challenging what he calls 'Mariomania,' the view that our engagement with Mars ought to be dictated by the interests of microbial life forms if any of the latter are found. This view is exemplified by Carl Sagan's call to accept that Mars would belong to the Martians, if there were any, and even if they were microbial. Rather than focusing upon the familiar arguments which are found in Cockell, in the environmentalism-influenced literature and in Smith's earlier papers, he instead challenges the ethical underpinnings of such an approach through a critique of its appeal to inviolable principles concerning life-forms, and by appeal instead to a form of ethical pragmatism that highlights the considerable opportunity costs of foregoing the human exploitation of Mars. In this way Smith touches upon the deep background intuition that sometimes motivates scientific opposition to inherent value arguments. In Chap. 15 Sean McMahon shifts the ground for planetary protection away from matters of microbial value towards the appeals for and against the terraforming of Mars which draw upon aesthetic considerations. McMahon argues that Mars may offer distinctively Martian forms of beauty that we are not yet in a good position to fully appreciate but which might be brought more fully into the public consciousness by future exploration. In a cautiously formulated claim, McMahon suggests that recognition of such beauty would provide at least a defeasible reason for caution about terraforming. As elsewhere in the protection literature, reasons for caution do not necessarily translate into any comprehensive 'hands-off' attitude.

The final cluster of papers tackle matters of legality and risk. In Chap. 16 'The Way to Eden,' Christopher Newman points to the consensus about damage caused by existing space activities and looks towards the possibility of a more sustainable approach. Newman argues that any new regulatory framework should embed a commitment to environmental protection and that this should be at the forefront of policy discussions. The thought here does not simply concern the legal and ethical issues raised by the prospect of a human-crewed mission to Mars, but rather the template for all long duration space flight. Behavioral norms and regulation are taken to go together in the paper rather than the former constituting the need to circumvent the latter. From environmental protection, Paul Graves moves into the territory of human risk in Chap. 17 considering the danger of high velocity fallback accidents in the case of nuclear powered probes. Such accidents could spread radioactive material across a broad area and although fallback accidents are uncommon, Graves' utility analysis suggests the likelihood of an unacceptably high expected loss of life, one which would not be adequately justified by appeal to the expected returns from science probes. Consequentialist and deontological critiques of current practices are therefore accepted as broadly correct with the upshot that the associated deep space programs should not be abandoned but modified, to properly acknowledge the dangers.

The final chapter, by Frans von der Dunk, 'Shaking the foundations of the law: some legal issues posed by a detection of extra-terrestrial life,' takes us to the widest reaches of our aspirations in space: the discovery of other intelligent life forms and the legal issues that this would pose. If such beings possessed intelligence of a lesser sort and had no concept of law, would it be legally permissible to treat them as objects of our law, with rights requiring advocacy (rather like animals) instead of agents who might speak for themselves? If they had a similar intelligence and their own concept of law, then whose law should be upheld? The argument is made by von der Dunk for a compromise 'meta-law', arranging the respective spheres of application of human-made law and the comparable extra-terrestrial legal system. However, if they possessed greater intelligence (a scenario considered already in the Baum paper) we might instead become the 'object' of their system of 'law.' These considerations are used by von der Dunk to problematize our sense of the stability of law in the face of a possibility of discovery that space exploration poses.

The aim throughout the book has been to provide a series of ethical encounters that will help to set out, illuminate and stimulate key arguments and help to mark the arrival of space ethics at a new stage in its development. The editors are indebted to the initial encouragement of the Space and Society series editor Douglas A. Vakoch for helping to shift the idea for a volume from email exchanges to something more concrete; to Alessia Valdarno and Ramon Khanna at Springer for ongoing guidance and support; to the contributors for their patience and diligence, to Mukhesh Bhatt for providing valuable commentary on a cluster of these papers at an Ethics of Space Exploration workshop held at the University of Hertfordshire in 2015 and to numerous friends and colleagues across the space community for their interest and commitment to the importance of ethical deliberation.

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Part I
The Cultural and Historical Context of Space Ethics

Chapter 2
Dreams and Nightmares of the High Frontier: The Response of Science Fiction to Gerard K. O'Neill's *The High Frontier*

Stephen Baxter

2.1 Introduction

> 'Centurion, the cylinder is nearly three thousand miles long.'
>
> 'Three *thousand*—'
>
> 'That is more than the diameter of Luna, sir. The end hubs alone could swallow a small moon. The land area within must be similar to that of the whole of Asia … The question is, of course, who would live in such a structure—'
>
> 'I can tell you that, *optio*, 'Quintus said. '*That's* where the emperor will be. And the very rich. Living off the huge rivers of goods that flow between the worlds.'
>
> 'An emperor become a god,' Titus said. 'I wonder how you could ever get rid of him?' Quintus grinned back. 'Good question, Titus.'
> (Baxter 2014, 268–269)

This paper concerns the imaginative response of writers of science fiction (SF) to the proposals for space colonisation developed by Gerard K. O'Neill and co-workers in the 1970s (O'Neill 1976a). (Elsewhere in the present volume Munevar explores criticisms of the O'Neill scheme from a wider audience.)

O'Neill is associated with large space-habitat designs such as the 'O'Neill cylinder' (ibid., 64ff). O'Neill's work is however largely sociological in intent rather than technological. He uses space-habitat designs as stepping-stones in a vision of a progressive future for mankind in the longer term, with small communities 'homesteading' the asteroids in an analogy with the American frontier experience. This is a very science fictional scenario, but O'Neill claimed that his scheme was based on economic and engineering logic, not on SF readings. And as will be seen, the reception of O'Neill's ideas by the science fiction field has been a

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complex one, and not always positive. The best of these fictional responses serve as thought experiments on the plausibility of the O'Neill space colonisation scheme, and the possible reality of human life within its parameters.

2.2 The Sociology of O'Neill and Precursors in Science Fiction

2.2.1 The O'Neill Prospectus

O'Neill's studies are associated with designs of large space habitat. Indeed such designs have become part of the imaginative furniture of the future; for example an O'Neill cylinder was featured, without explanation, in a brief scene towards the end of the movie *Interstellar* (2014, dir. C. Nolan). Such colonies regularly feature in prose fiction too, such as in Iain M. Banks' *The Algebraist* (2004). In the year 4034 AD, in a system called Ulubis twenty thousand light years from Earth, Hab 4409 is an O'Neill cylinder fifty kilometres long, 'a giant, verdant city rolled up into a spinning tube' (Chapter Three).

However, in O'Neill's scheme, large near-Earth habitats would be merely the first stepping stones into space. Their initial economic justification would be to sustain large populations of workers who would build orbital solar power stations (SPS), the output of which would be sold back to the Earth. Arguing from a premise that 10,000 workers in space would be needed to kick-start a significant industrial presence there (O'Neill 1976a, 116) O'Neill proposed as a model starter colony his 'Island One', a sphere $\sim$500 m in diameter, rotating twice per minute to provide Earth-equivalent gravity. This would be constructed largely from lunar resources and would host 10,000 people living at urban population densities. Island Two would be an expanded version with a population scaled up to 140,000 people, and O'Neill's Island Three (ibid., 64ff) was to be a pair of rotating cylinders each 32 km long and hosting a population of 20 million (ibid., 69).

Once humanity was established outside the gravity well, a wider strategy would unfold, with the islands used as bases for further expansion into space. For the space colonies to achieve economic independence from Earth, they would need an extraterrestrial supply of compounds of carbon, nitrogen and hydrogen—materials not available from the moon, but from the asteroids (ibid., 251). Thus O'Neill imagined small groups of people equipped with relatively simple spacegoing technology able to set off from the first islands to 'homestead' the asteroids (ibid., 233), making a living by selling essential materials back to the space colonies.

The consequent transformation in the fortunes of humanity would be dramatic. O'Neill predicts a rapidly bootstrapping human expansion into the solar system, with an extraterrestrial population measured in billions within a few decades (ibid., 260), and a growth of economy and exploitation that would see the resources of the solar system consumed in a few thousand years (ibid., 247).

This was a very science-fictional plan. But O'Neill's visions do not, however, seem to have been influenced by prior science fiction.

2.2.2 *Space Colonisation in SF Before O'Neill*

O'Neill makes clear that the source of his inspiration was social, not technological: 'Often people have asked why I picked as our first question: "Is a planetary surface the right place for an expanding technological civilisation?" There is no clear answer, save except to say that my own interest in space as a field for human activity went back to my own childhood, and I have always felt strongly a personal desire to be free of boundaries and regimentation' (ibid., 279). While he claims to have read SF as a child (ibid., 60) he recalled no mention of space habitats as an arena for human civilisation, as opposed to moons and planets: 'As a reader of science fiction in childhood, I gained no clue that the future of mankind lay in open space rather than on a planetary surface. Later … logic and calculation forced me to that conclusion' (ibid., 60). He was directed to Tsiolkovsky's fiction, for example, only after his own first designs had been published. He would write, 'In a round-table TV interview, Isaac Asimov and I were asked why science-fiction writers have, almost without exception, failed to point us towards [space colonies]. Dr. Asimov's reply was a phrase he has now become fond of using: "Planetary chauvinism"' (ibid., 35).

However there were indeed precursor works depicting space stations and colonies dating back more than a century, many of which foreshadowed elements of O'Neill's studies. A comprehensive though somewhat dated survey of this SF subgenre was given by Westfahl (2009). These works were not developed in isolation; SF has always attracted a strong community, with readers and writers following each others' work and elaborating on and critiquing shared ideas. In addition there has been a constructive dialogue with philosophers, engineers and others working in the field.

It was in fact in an SF novel, by Konstantin Tsiolkovsky (1857–1935), a Russian scientist and writer, that the fundamental principles of space colonisation were first set out in a coherent fashion: that is, the use of abundant solar energy and other extraterrestrial resources to sustain a large, expansive human future beyond the Earth, the basic scheme that would underpin O'Neill's prospectus. *Vne Zemli* (*Beyond the Planet Earth*) (1920), set in the year 2017, features liquid-fuelled rockets that reach the moon in 4 days (chapter 3), the collection of solar energy in space (chapter 36), spin gravity (chapter 15), and large colonies in cylindrical sunlit 'greenhouses' positioned in geosynchronous orbit (chapter 29). The moon is rather dismissed as a source of raw materials for new colonies—but a near-Earth asteroid, as it would now be called, is prospected (chapter 51). In all this was a remarkably prescient and coherent vision of a human expansion into space.

As to the specific design of space habitats, it was in the famous *Collier's* magazine articles of the 1950s by von Braun and others (Ryan 1952) that the first

coherent post-World War II plan for space travel with soundly based engineering was publicised, as developed by the engineers who would go on to drive the US space programme in the 1960s and beyond. And the centrepiece of the study is a wheel-shaped Space Station. It cannot be denied that Von Braun's wheel design has become imprinted on the popular imagination, as 'the' classic space station architecture. The movie *2001: A Space Odyssey* (1968, dir. S. Kubrick) shows perhaps the most famous fictional wheel-in-space, Space Station V, at which Dr Heywood Floyd transfers from an Earth-to-orbit shuttle to a lunar ferry.

But many decades earlier, some SF writers had been led through the engineering logic of spin gravity to anticipate the 'O'Neill cylinder' (Island Three). Williamson's 'The Prince of Space' (1931) is a pulp-fiction saga of the attempted invasion of Earth by plant-like vampire Martians. The eponymous rogue's habitat is a spinning cylinder 5000' (1520 m) in length and diameter, and home to 5000 people. It is an authentically realised O'Neill habitat: 'It gave Bill a curious dizzy feeling to look up and see busy streets, inverted, a mile above his head. The road before them curved smoothly up on either hand, bordered with beautiful trees, until its ends met again above his head' (Chapter 3).

Just as decades of precursor SF prepared humanity for O'Neill's visions, so responses to his schemes would be expressed in fictional form after his first publication.

2.3 Utopias on the Space Frontier

2.3.1 First Reactions

It is easy to see why O'Neill's ideas struck a chord with space advocates. O'Neill's work produced the first detailed post-Apollo space colony designs to be based on plausible modern materials and technologies. He devised a fresh synthesis by integrating old ideas, such as the lunar mass driver, with new results such as the post-Apollo analysis of lunar rocks and their mineral content and potential for use as construction materials. The idea of selling solar energy to the Earth was a new justification for large stations in orbit. His results were analytical, numerate, and compellingly argued.

Not only that, O'Neill published at a time when space exploration had only recently revealed the worlds of the solar system, notably the moon and Mars, to be much less promising in terms of colonising potential than had once been thought: 'When Mariner IV looked on the face of Mars and found only a dead world … a frontier died that afternoon,' space advocate and SF writer Jerry Pournelle would write (1979, 1). Now a vision of habitable destinations in space itself, as opposed to on those disappointing worlds—recall that O'Neill used the term 'islands' to describe his first colonies—would evoke a response from space dreamers of all kinds.

An immediate and generally enthusiastic first response to the O'Neill prospectus was a two-part anthology edited by Pournelle (1979–1982) consisting of original stories and reprints dating from 1975 to 1979. These roughly track through the steps of O'Neill's proposed advance into space. 'Spirals' by Niven and Pournelle is about a race to complete the building of the first O'Neill colony, called the Construction Shack: 'I was a tiny chick in a vast eggshell' (ibid., 36). As the economy on Earth collapses, the US administration steadily cuts back on the station's funding, until the crew convert the station into a ship and sails out to the riches of the asteroid belt. The conflict between the visionary spacers and the short-sighted Earthbound and their governments, called 'downers' here, is characteristic of these stories—and in such polemic pieces the 'downers' are portrayed entirely negatively. Pournelle's own 'Bind Your Sons to Exile' is about the first fully fledged asteroid mine, but just as in 'Spirals' opposition from sceptics on the ground starves the project of funding: '"Boondoggle" was the kindest word they had for us' (ibid., 256).

As for life in the habitats themselves, perhaps the most interesting of the stories here is Sheffield's 'Transition Team', in which a 3000-person O'Neill colony is having significant trouble with its young people. The 'space-born' show no interest in the colony's Earth-related goals. Instead they are drawn to the zero-gravity axis region, the most authentically non-terrestrial environment, where they develop new ways of moving, new forms of art. '[For the children] the Colony … is the only *real* world, the only one that matters … As for us [adults], we've served our purpose. We were just the transition team' (ibid., 348–350). Perhaps this is predictive of a problem for real-world colonies. Without careful social engineering and education, there seems no a priori reason why 'space-born' children should care remotely about a world they have never visited, or about goals devised by their parents long before they were born.

2.3.2 *The Space Enthusiasts*

With time, O'Neill's proposals inspired much more extensively developed visions of the 'high frontier', many of them quite utopian. From 1989 American author Allen Steele., in the early novels of his 'Near Space' future history sequence (1989, 1990), seized on the basic O'Neill plan and used it to spin dreams of blue-collar workers in space. While these books are ostensibly gritty and realistic, they are at the same time extraordinarily romantic—and are heavily influenced by similar works by Heinlein several decades earlier (compilation 1977). *Orbital Decay* (1989) is a projection from the then present in which, by the late 1990s, the major corporations have moved into space activities, notably Skycorp. Set in the year 2016, the drama is centred on Skycorp's wheel in space, the Olympus Station, known as 'Skycan' by the workers aboard. Nearby is the zero-gravity facility Vulcan Station, used to construct SPS satellites from lunar aluminium (ibid., 80). And under cover of 'Meteorology' studies, national security operatives are

constructing a 'Big Ear', a covert facility capable of monitoring telephone and other conversations anywhere on the planet.

Steele deliberately contrasts this working environment with the 1950s von Braun visions, with their 'spit-and-polish Air Force types going around saluting and eating food capsules' (ibid., 33). Like an oil rig, the purpose of the enterprise is to extract energy from an inhospitable environment, and the workers fit the situation: 'These guys are mainly blue-collar, salt-of-the-earth, hard-hat types, with a wild-ass streak … They don't want to hear discourses about a manifest destiny among the stars, they want to make a bundle at a high-risk profession and get home alive' (ibid., 210). However, Steele has his workers rise up against what they see as the anti-democratic activities of the Big Ear project; in the end they see themselves as pioneers in the American tradition, and it is 'the right of pioneers to decide what happens on the frontier' (ibid., 316).

The sequel, *Clarke County, Space* (1990), set a generation on in 2049, is about a more fully committed space colony. Hosting some 8000 people the eponymous colony is centred on the 'biosphere', a rotating sphere of radius $\sim$110 m (ibid., 26). The conflict concerns the destiny of the habitat. Its inhabitants see it as a seed bed for the human expansion into space; it aims to become self-sufficient, it hosts agricultural experiments (ibid., 52), and there are dreams of spawning more colonies off in the asteroid belt. On the other hand in the here and now it is still a 'company town' (ibid., 53) and its corporate controllers, seeking a quick return on their investment, use it as a tourist resort. Again the frontier spirit prevails, and a movement begins for the colony to declare its independence: 'This colony—this community—will not be bought-and-paid-for by a bunch of corporate greedheads who want to turn it into a tourist trap.' (ibid., 55).

But for some writers O'Neill's vision was always ambiguous. Set somewhat further in the future, Katherine MacLean's 'The Gambling Girl and the Sinful Hell', a story in the generally positive Pournelle anthology (1979), is a tall story of a family homesteading the asteroids in a one-family spacecraft of the kind O'Neill advocates: 'Abe was getting too big for the home barrel …' (ibid., 267). This folksy story of a widowed mother and her kids sharing their 'barrel' with chickens and piglets may echo fantasies of little houses on the prairie. But to many readers the confinement and isolation the children endure will seem stark: 'The girl was staring around at a circle of faces … We'd hardly seen anyone new except Sam and MacPherson whose orbit was almost the same as ours …' (ibid., 273). Isolation and a dependence on communal systems for the basics of survival could of course make small or large colonies naturally tyrannous environments (Cockell 2013), in direct opposition to O'Neill's dreams of freedom and progress.

Thus even the most positive of stories about O'Neill colonisation could contains seeds of doubt. And with time more critical fictions would be written.

2.4 Dystopias in Space

2.4.1 Economic Doubts

Through the 1980s the O'Neill model was closely inspected in fictional works and beyond, and doubts were formulated, objections raised. For example, against a background of a reduction in energy costs after the oil crises of the 1970s, the economic model for the space islands' proposed development based on SPS looked less promising.

Trojan Orbit by Reynolds and Ing (1985) is an entertainingly searing critique in fictional form of the O'Neill vision. In the (then) near future, while the Soviets patiently build a modular station of the Mir-ISS type, the west has invested in the O'Neill dream, with 'Island One' having been established at L5, whose inhabitants are intended to be building SPS plants and further colonies. However, the authors argue, the practicalities of the project have simply not been thought through. They quote a paper of O'Neill's in *Futurist*: 'The first space community would house 10,000 people; 4,000 would be employed building additional colonies, while 6000 would be producing satellite solar power stations'. 'Wizard, but who was supposed to be running the island? Who was going to be keeping the hydroponic farms going, regulating the air and water …? Who was going to be teaching the kids? Who was going to be taking care of the hospitals?' (O'Neill 1976b, 129). It ultimately emerges that the colony is a huge racket, controlled by organised-crime families in order to siphon off the billions of dollars' worth of investment in the station. The book is dated and lurid, but perhaps it should be required reading for all O'Neill advocates.

Meanwhile, aside from the economics, how would it be to live in such habitats?

2.4.2 Cages in Space

Space colonies, floating in the vacuum, may paradoxically feel like burrows in the ground. In addition to metres-thick layers of moon rock to provide radiation shielding, plants grown in space would need windows of lunar glass $\sim$10 cm inches thick to protect them from raw, unfiltered sunlight. The inhabitants would not even be able to see out, to see that they were in space. Such habitats could seem very unwelcoming places, and this was reflected in fiction. One ghastly glimpse of the result of long-term exposure of workers to microgravity is Kelly's story 'Breakaway, Backdown' (1996): 'Her muscles have atrophied so her papery skin looks as if it's been sprayed onto her bones … "I've got 40 % bone rot … and I mass 38 kilos … This is how space makes us over.'

A brand new space habitat would no doubt be an attractive destination. But what happens when the technology grows old and break down? In Sterling's *Schismatrix* (1985), a dramatic vision of a posthuman future in the solar system and beyond, the