

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 ~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 ~ 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 contain 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 ~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

Concatenate is a federation of O'Neill-type colonies orbiting the moon, habitats built in the twenty-first century but by the book's opening in the twenty-third century historical relics. Like modern-day Detroit, the 'Mare Tranquillitatis People's Circumlunar Zaibatsu' is a city in space that has become bankrupt. Entering, the protagonist 'could stare the length of the Zaibatsu, through five long kilometres of gloomy, stinking air ...' (ibid., 11) Internal society has broken down, with people living in shacks built from ruined factories and sealed against the disease-laden air (ibid., 22). The ghastly truth is that the inhabitants of this orbital slum have nowhere to go, no chance of economic recovery, no prospect of salvation from their plight.

Another troubling aspect of space habitats is their inherent fragility. O'Neill dismisses the dangers of terrorism to space habitats, thanks to the possibility of screening at limited access facilities, and, so O'Neill claimed, the difficulty of an individual doing large scale damage to a habitat (1976a, 111). But Sterling (1985) argues that living in such fragile habitats would condition the psychology of the populace: '*Worlds could burst ...* Outside those locks loomed utterly pitiless darkness ... There was no true safety ... There were a hundred ways to kill a world: fire, explosion, poison, sabotage ... The power of destruction was in the hands of anyone and everyone ... The spectre of destruction had shaped the moral paradigm of every world and every ideology' (Sterling 1985, 64).

In Gibson's *Neuromancer* (1984) L5 habitats, part of the furniture of a heavily corporate future, are presented entirely negatively: 'Archipelago. The islands. Torus, spindle, cluster. Human DNA spreading out from gravity's steep well like an oil slick' (ibid., 125). Even the builders of Freeside, a massive cylindrical habitat (ibid., 132) which, with its hotels, brothels and casinos, dominates an archipelago of settlements (ibid., 149), have turned inwards, creating a colony hidden within the habitat which is compared in horrific terms to a wasps' nest (ibid., 204).

This peculiar introversion, this burrowing inward, is a common feature even of utopian visions of space habitats. In the superficially attractive cylinder-world glimpsed in the movie *Interstellar* (2014), it is impossible to see out into space, and the architecture is that of the past, of an idealised American small town folded on itself. It is almost as if the characters are not in space at all. This sense of a retreat inwards and to the past can feel at odds with the generally progressive, future-oriented nature of much SF discourse.

Meanwhile, other authors have depicted O'Neill habitats not as shelters for workers but as castles in the sky for elites.

2.4.3 *A Celestial Elite*

The idea of space habitats housing a *benevolent* elite is featured for example in Sagan's *Contact* (1985). The attraction of space for the elderly wealthy is the suggestion of longevity in zero gravity conditions: there is 'the faintest aroma of immortality' (ibid., 281). By the year 2000 there are 'rudimentary retirement hotels'

in Earth orbit. There are qualms: ‘It was foolhardy, they said, to permit an elite class to emigrate to space, with the masses left back on Earth—a planet in effect given over to absentee landlords’. But Sagan takes an optimistic view of the effect of space on its elite colonists: ‘Hardly anyone anticipated the principal outcome, the transfer of a vivid planetary perspective to those who would do the most good’ (ibid., 282). Indeed it is a consortium of the orbital wealthy who lead the final construction of the alien ‘Machine’ that takes Ellie Arroway to the stars. Speculation on the medical benefits of space habitation had already dated back decades; see for example Clarke (1968, 151), who had outlined possible advantages for serious burns victims, post-operative therapy, and the ‘possibility—wildly speculative ... that the expectation of life may be increased when the wear and tear of gravity is removed.’

Meanwhile the idea that a wealthy elite in space habitats may *not* necessarily prove to be benevolent has been explored since some of the earliest fictional reactions to O’Neill’s pioneering studies. In particular, it is surely a weakness of the O’Neill blueprint that the planet’s vital energy supply could be easily controlled by a handful of people in space. In Ben Bova’s *Colony* (1978), in the year 2008 Island One is an O’Neill cylinder, ‘landscaped, filled with air, an engineered paradise that housed an elite few of very rich people—while billions lived in misery on the tired, crowded old Earth’ (ibid., 10). The habitat is the hub of a solar power industry. Five super-wealthy individuals known as the Board are controlling access to space power; they seek to destroy a World Government which, by trying to force them to use their profits to alleviate social problems, they see as an obstacle to their own ambitions. Ultimately Island One, and a private second cylinder, will be the final refuge of the super-rich, while Earth burns (ibid., 107).

In Joe Haldeman’s *Worlds* novels (1981–1992), in the 2080s 21 space habitats, ‘Worlds’, orbit an overcrowded Earth. The largest is New New York, with a quarter of a million inhabitants. While politically independent, New New York is economically in debt to the US after cheap fusion ended the economic justification for SPS, and it depends on organic materials from Earth—but when lodes of such material are found on the moon, the prospects of the Worlds are transformed. However this initiates tensions with Earth. The crisis comes when New New York, in a show of force, cuts the power from its SPS stations to the US. After a devastating war the Worlds become refuges of civilisation, orbiting a ruined Earth. The 2013 movie *Elysium* (dir. N. Blomkamp) portrays a similarly bleak view of elitism in a space colony. Director Blomkamp was inspired by a *National Geographic* report on the 1970s Stanford Torus design (Johnson 1977) to imagine a kind of gated community in space, ethereally beautiful; the half-million citizens of Elysium, having fled to the sky, ruthlessly exploit an Earth ruined by environmental collapse and over-exploitation. At least one veteran of O’Neill’s work (Brody 2013) objected to the subversion of utopian studies from 1970s California into a twenty-first-century portrayal of an instrument of oppression.

2.5 New Social Orders: Fragmented Cultures and Limits to Growth

2.5.1 *The Fragmentation of Mankind*

As noted above, one distinctive feature of O'Neill's scheme is that, despite his famous designs for large space habitats, he sees a long term future in which freedom for mankind is secured through its scattering into a series of much *smaller* communities. More generally, O'Neill argues (1976a, 17) for any technological improvement being beneficial only 'if it reduces rather than increases the concentration of power and control ... if [such improvements] *tend to reduce the size of cities, industries and economic systems to small size*, so that bureaucracies become less important and direct human contact becomes more easy and effective' (my italics). The 'evils of bigness' include 'high crime rates ... social alienation, and political corruption' (ibid., 39). And human communities need room to experiment. Since we have yet to have found an ideal government form, 'what chance for rare, talented individuals to create their own small world and family, as was so easy a century ago in our America as it expanded into a new frontier?' (ibid., 40).

In addition O'Neill sees growth as a buffer to freedom and happiness. O'Neill argued that human freedom could be assured by giving people the ability and the room to move and build a new society for themselves. He argues against imposed limits of all kinds: 'The freedom to have as many children as a family wants is by no means as important as the freedoms of speech, communications, travel, choice of employment, and the right to an education, but it is hard to abrogate one freedom without compromising others' (1976a, 246). In O'Neill's model of the future, it may seem that the evolution of human society is driven by irreparable flaws in our own nature. Our inability to build stable large communities must lead to the fragmentation of society, and our inability to control our population numbers must lead to endless fissioning, movement and growth.

But are there plausible, and desirable, alternatives?

2.5.2 *Melting Pots*

There are in fact technical arguments in favour of large habitats rather than small, such as given in Fogg's discussion of contained biospheres (1995, 48ff). While the functioning of biospheres is imperfectly understood, Fogg argues that it may be impossible to scale down Earth's biosphere by many orders of magnitude (five orders down from Earth to an O'Neill cylinder) and expect it to maintain all its functions adequately. And the smaller the size of container, the more conscious intervention is likely to be required maintain the habitat.

In addition there may be scientific or other reasons why large habitats could be desirable. For example, could space habitats serve as wildlife refuges? In Robinson's *2312* (2012), set in the twenty-fourth century as the title suggests, mobile habitats called 'terraria' (ibid., 36–40) are typically hollowed-out asteroids comparable in size to O'Neill's Island Three. There are nineteen thousand terraria, some given over to farming, others used as reserves for species threatened on a post-climate-change Earth. There are even ecologies containing creatures extinct but restored, such as a terrarium called *Pleistocene* containing Ice Age flora and fauna (ibid., 59). This idea dates back to suggestions by O'Neill himself that space islands could be used as wilderness refuges (1976a, 253). But this too was predated by the wistful vision of the movie *Silent Running* (dir. D. Trumbull, 1971) which showed domed forest reserves held in orbit around Saturn, with the ultimate intention being to 'refoliate' an Earth that seems to have become a bland, nature-free utopia.

Note however that Robinson's terraria are not very large in terms of the space needed by wildlife in nature. A wolf pack, consisting of ~ 10 animals, may have a territory of 35 km^2 (Jędrzejewski et al. 2007). A Robinson terrarium with an inner surface area of $\sim 160 \text{ km}^2$ would have room for only ~ 4 packs, or ~ 40 individual animals, a small population in terms of genetic diversity and the salvation of a species. Even an O'Neill colony is probably too small to contain wilderness.

As regarding social issues, given prior examples on Earth, even if a peaceful partitioning of communities is achieved it may not always be a happy solution. How to decide, among the descendants of the pioneers who built a habitat, who should stay and who should go? And what may look like a healthy parting of the ways to one group might look like cleansing (ethnic, religious, ideological) to another.

One American voice to provide a counter-argument against the fragmentation of mankind in space was Isaac Asimov, in his novel *Nemesis* (1989). In the 23rd century the solar system is divided between an overcrowded Earth and a sky full of 'Settlements'. The Settlements stand aloof from Earth, which they regard as an 'unliveable slum' (ibid., 47)—and also from each other, if only for the fear of infection from diseases bred in separate, isolated biospheres: 'Commerce is being throttled for fear of picking up someone else's strains of parasites or pathogens' (ibid., 29).

Further, the Settlements themselves are portrayed as unhealthily cleansed socially: 'On any Settlement, all are alike, or, if there is some admixture to begin with, those who are well outnumbered feel ill-at-ease, or are made to feel ill-at-ease, and shift to another Settlement where they are not outnumbered ...' (ibid., 130). This is a rejection of a tradition of relative tolerance which perforce has had to evolve on Earth. 'We're talking about Earth's long struggle to find a way to live together, all cultures, all appearances. It isn't perfect yet, but compared to how it was even a century ago, and it's heaven. Then when we get a chance to move into space, we shuck it all off and move right back into the Dark Ages' (ibid., 156–157).

There have been other wistful depictions of large space habitats as places of peaceful encounters: 'It was the dawn of the third age of mankind, 10 years after the Earth-Minbari War. The Babylon Project was a dream given form. Its goal: to

prevent another war by creating a place where humans and aliens could work out their differences peacefully ... Humans and aliens wrapped in two million, five hundred thousand tons of spinning metal, all alone in the night ... The year is 2258. The name of the place is Babylon 5' (opening narration, season 1). The deep space station Babylon 5, star of the eponymous TV series (Babylonian Productions, 1994–1998), is a large O'Neill cylinder located in orbit around a planet of Epsilon Eridani, and capable of supporting 250,000 human-scale entities in a variety of gravity regimes. In a crowded and conflict-filled Galaxy, the station was established at a contact point of five major interstellar powers, and became a junction of inter-species diplomacy.

In the TV series *Star Trek: Deep Space Nine* (Paramount 1993–1999), meanwhile, the eponymous space station, a glorious, Gothic wheel of immense proportions, was built in orbit around the planet Bajor by the occupying Cardassians. When the occupation was lifted the Bajoran government invited the United Federation of Planets to jointly administer the station, and with a nearby wormhole offering access to the 'Gamma Quadrant', a remote part of the Galaxy, the space station becomes a multicultural centre for interstellar exploration, trade, politics. Even in the movie *2001: A Space Odyssey* (1968), a space station meant as a mere waystation was a place where Cold-War American and Soviet scientists could at least meet over a drink.

2.5.3 *Freedom Within a Habitat*

As we have seen O'Neill argues that the ability to escape a habitat is a necessary buffer to human freedom. But is a free society possible without this safety valve? Of course even the largest single habitat must have limits to population growth—and there may be other unexpected constraints on the inhabitants' freedoms. Grant (1984), in the context of world ship designs, studied the stability of populations in such habitats under various regimes. The results of his computer-modelling are complex, but since in the long term a *fall* of population, causing a loss of capability and genetic variability, is as damaging as a resource-depleting population excess, it may be that in some circumstances inhabitants would be compelled to *have* children.

More generally, is freedom possible without growth? A *static* society, of the kind described in the Club of Rome's 'Limits to Growth' report (Forrester 1971), is economically at least a feasible solution to the conundrum of survival in a space colony. O'Neill (1976a, 27) himself points out that steady-state societies are possible, and cites the pre-Conquest Inca empire as an example—but a negative one: 'at his death [an Inca peasant] ... left a world almost exactly the same as the one he was born into'. In his view, such a society is 'rigidly structured, dictatorial'; 'almost any static society is forced in self-defence to suppress new ideas'. In the author's own fiction the Inca-dominated habitat in *Ultima* (2014) is a static society but an

autocratic one; excess population is creamed off for labour on extraterrestrial mines, the military and other activities.

Nevertheless, in a world that seems even more tightly constrained by resource limits than those faced by the authors of the ‘Limits to Growth’ studies of the 1970s, there are modern studies in how prosperity, including spiritual growth, could be achieved without endless material and economic growth (Jackson 2009). Possibly by the time we inhabit large colonies in space we will necessarily have learned how to live within steady-state societies on Earth without compromising our essential human freedoms; with new goals and new motivations, such ways of living might be readily transferred to life in space habitats.

But, even if individuals can escape from habitats to go homesteading in the solar system, there are still more fundamental limits to growth.

2.5.4 *A Finite Solar System*

O’Neill argues that modest growth ‘will encourage the extension rather than the curtailment of freedom ... I’ve argued that a growth rate about a tenth as large as the present explosive increase would make the difference between stasis and change ...’ (1976a, 247). Even at low rates, growth requires room. O’Neill imagined individuals leaving large habitats and homesteading new terrains, a movement that would naturally lead to a solar system full of colonies. We glimpse swarms of diverse habitat-based communities in Gibson’s *Neuromancer* (1984), and Robinson’s *2312* (2012) shows a solar system full of inhabited asteroids. But there are limits to growth even in the solar system. O’Neill himself speculates (1976a, 247) that the resources of the asteroids, equivalent to the surface area of 3000 Earths, might fill up, even at the modest growth rates he predicts, in a few thousand years; exploiting the more remote resources of the solar system might allow expansion for several more thousand years.

And what then? Is our destiny, driven by the imperative to growth, to move beyond the solar system?

2.6 An Arena of Ultimate Dreams

Since the works of Tsiolkovsky (1920) and Bernal (1929) some thinkers have speculated on the largest scales about the ultimate destiny for humanity and human civilisation in space. The author’s own ‘Open Loops’ (2000) is an account of a future colonisation of interstellar space by post-humans fully adapted to the zero gravity conditions of asteroid habitats. Ten thousand years after its first colonisation, asteroid Ra-Shalom is a ball of liquid containing fish-like post-humans subsisting in an ecology essentially shared with blue-green algae. After a million years, the nearby stars glow green, surrounded by clouds of such habitats.

Perhaps the ultimate fictional realisation of these most spiritually expansive of space-colony dreams is Zebrowski's *Macrolife* (1979). Zebrowski references O'Neill, though his direct inspiration (afterword) was the work of Cole (1961). In the year 2021, mankind's first large space habitat is Asterome (Chapter 6), a 'mobile utopid' located at L5, a hollowed-out asteroid some ten miles long and five miles across. Hosting 100,000 people, it has become a centre of industry, research and colonisation. However a disaster overwhelms the Earth and Asterome flees to the stars. By the year 3000 new 'macroworlds' have been produced at such stars as Alpha Centauri and Procyon. Asterome itself has some properties of a larger life form, 'macrolife'; it is able to 'reproduce' by shedding outer layers, to leave a hollow shell into which a raw asteroid is taken for reworking. It now emerges that macroworlds are a convergent goal for many forms of life: 'Macrolife was the brain and nervous system of something being born all over the Galaxy' (chapter 25). A staggering coda to all this is set a hundred billion years hence, as the universe faces a termination through a Big Crunch. Some of the macroworlds manage to survive the terminal singularity, and encounter what appear to be relics of still earlier cycles.

All this is a long way from O'Neill islands at L5, huddled in their cloaks of moon rock, earning money from clunky solar-power stations. But perhaps a space advocate would argue that such visions express the ultimate ethical choice concerning space colonisation: to ensure the survival of the human species into the very far future, or not. On the other hand, perhaps O'Neill is wrong about the fundamental imperatives behind mankind's growth; perhaps we will after all learn to live within our means. As SF writer Brian Aldiss once remarked from the audience in response to a speech of the author's on expansion in space, 'But we've heard all this before! If only we could get along with each other, we wouldn't have to go to all the trouble of conquering the Galaxy!' (Novacon 23, 1993).

2.7 Conclusions

'The glass sunlight panels were coated with filth ... A cadre of lumpy robots were scraping and mopping the fretted glass ... Lindsay realised suddenly that they were human beings in suits and gas masks' (Sterling 1985, 13).

Writers of science fiction have responded imaginatively to the proposals for space colonisation developed by O'Neill and co-workers in the 1970s. Post-publication response to O'Neill's utopian vision in SF has been positive from some writers who welcomed to the idea of a new frontier. But others were critical, foreseeing such drawbacks as the destruction of the health of space workers, the grimness of life in a failing habitat, coercion by corrupt elites, and the unhealthy fragmentation of mankind.

In the forty years since O'Neill's first publication, continuing fictional explorations constitute a bank of thought experiments on how O'Neill's ideas might play out in reality and their impact on humanity. As to the predictive accuracy of these tales, only time will tell.

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