Asteroid Mining and the Enclosure of Outer Space: New Space Economy Discourses and Ethnofuturist Critique

Craig Henry Jones, BA(Hons), M.Res.

This thesis is submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy.

Lancaster Environment Centre, Lancaster University

September, 2021

Word Count: 73,208

I declare that this thesis is my own work; has not been submitted in substantially the same form for the award of a higher degree elsewhere; and that the word length conforms to the permitted maximum.

Craig Henry Jones, September 2021

Ideas in this thesis have been published in the following:

Jones, C. H. (2021), 'Enclosing the Cosmos: Privatising Space and Voices of Resistance', *Society and Space*, https://www.societyandspace.org/articles/enclosing-the-cosmos-privatising-outer-space-and-voices-of-resistance

Jones, C. H. and Whittle, R. (2021), 'Researcher Self-Care and Caring in the Research Community', *Area, 53(2)*, pp.381-388.

Jones, C. H. (2021), 'Planet of People: A Timely Provocation'. In: Batakyte, M. (ed), *Lithuanian Space Agency: Annual Report No. 1*, Vilnius: Six Chairs Publishing.

Jones, C. H. (2019), "Terracentric Positionings." In "Social Studies of Outer Space." https://stsinfrastructures.org/content/terracentric-positionings/essay . In: Innovating STS Digital Exhibit, curated by Aalok Khandekar and Kim Fortun. Society for Social Studies of Science. August. [Curated online essays].

Jones, C. H. (2019), "Capital, Power, and Outer Space." In "Social Studies of Outer Space." https://stsinfrastructures.org/content/capital-power-and-outer-space/essay . In: Innovating STS Digital Exhibit, curated by Aalok Khandekar and Kim Fortun. Society for Social Studies of Science. August. [Curated online essays].

Tutton, R., Vidmar, M. and Jones, C. H. (2019), 'Regeneration or Regurgitation?', https://stsinfrastructures.org/content/regeneration-or-regurgitation/essay . In: Innovating STS Digital Exhibit, curated by Aalok Khandekar and Kim Fortun. Society for Social Studies of Science. August. [Curated online essays].

Alvarez, T., Clormann, M., Jones, C. H., Taylor, A. R. E., Tutton, R. and Vidmar, M. (2019), "Social Studies of Outer Space". https://stsinfrastructures.org/content/social-studies-outer-space-1/essay . In: Innovating STS Digital Exhibit, curated by Aalok Khandekar and Kim Fortun. Society for Social Studies of Science. August. [Curated online essays].

Acknowledgements

The PhD has been an ambition of mine for a long time and, despite the many challenges it has posed, I am immensely grateful to so many people for their support in achieving this. Words cannot adequately describe how thankful I am to so many fantastic friends, family, and colleagues!

First and foremost, I would like to thank my various supervisors throughout this project: Professor Nigel Clark, Doctor John Childs, Doctor Richard Tutton, and Doctor Rebecca Ellis. Special thanks to Nigel who has supervised me on this project throughout its entirety: from applying for funding to final submission. They have all helped guide me throughout this process and provided fantastic support and feedback. I would also like to acknowledge the financial support provided by the ESRC.

Of course, this research could not have been produced without the support and time of the research participants. Thank you for contributing to this work through your interviews, sharing your perspectives and helping to develop this research and challenging me.

I cannot begin to express my gratitude to my family and friends. My family's relentless support throughout my education has provided me with sure-footing and a warm embrace throughout the challenging times of the PhD. When I have considered giving up, their love and support have encouraged me to keep going. This support has been added to through the kindness and love of my fantastic partner, Ellie Fielding-Redpath, and friends and colleagues who have been relentless in their capacity to cheer me up whenever I was down, have been excellent in challenging me to improve my work, and phenomenal distractions to the ever-looming thesis. I cannot name you all, but I must specifically thank: Emma Long; William Lawrence; Katharine Howell; Declan Lloyd; Aaron Aquilina; Sam Robinson; Nils Markusson;

Beccy Whittle; Ian Bryan; Julie Hearn; Lewis Myatt; Edmond Zhou; Andy Harrod; Leigh Martindale; and Emily Winter – thank you all for each making the world a little more bearable.

Diolch yn fawr pawb!

Contents

List of Figures

List of Abbreviations

ASAT – Anti-satellite weapon

AU – Astronomical Unit

DSI – Deep Space Industries

ESA – European Space Agency

ESPI – European Space Policy Institute

GPS – Global Positioning System

ISRU – In Situ Resource Utilisation

JAXA – Japan Aerospace Exploration Agency

NASA – National Aeronautics and Space Administration

NEO – Near Earth Object

NSE – New Space Economy

SF – Science Fiction

SFF – Space Frontier Foundation

Abstract

The burgeoning involvement of private actors in Outer Space has led to the term 'NewSpace Economy' (NSE) being coined in 2005 (Valentine, 2012) and has seen the emergence of several high-profile asteroid mining companies within the last decade. These companies and associated actors have sought to position themselves and their speculative industry as foundational to creating and maintaining a permanent human presence in Outer Space, averting a climate apocalypse, and producing a 'trillion-dollar industry'. They do this through (re)imagining Outer Space, mobilising asteroid mining as a focal point for off-world imaginaries. The discourses espoused by these private actors perpetuate and extend capitalist and Eurocentric imaginaries that draw upon colonial histories and the 'frontier' imaginary.

However, despite the seeming dominance of this Outer Space futurity, these imaginaries are not going unchallenged. Instead, the seemingly hegemonic imaginary of EuroAmerican futurism is disrupted and challenged via the provocations and (re)conceptualisations offered by Ethnofuturists and their work(s): producing futurisms that destabilise capitalist and Eurocentric imaginaries that implicitly and explicitly draw upon colonial, 'frontier' imaginaries.

This work theoretically and empirically engages with the nascent asteroid mining sector, seeking to decentre capitalist, Eurocentric, and terracentric imaginaries. It uses empirical data generated through a multiple method approach: interviews, participant observation, textual analysis, and grey literature combining to produce an empirically-grounded examination of asteroid mining and the means by and through which this is problematised. Through this corpus of data, it critically examines the way(s) NSE actors are 'opening' Outer Space for capitalist exploitation, how this domain is being 'enclosed' to secure

and maintain private ownership, before moving on to explore how the asteroid mining 'frontier' is being critiqued and reimagined by Ethnofuturists.

Chapter 1: Introduction

In late 2020, NASA's *Hubble Telescope* obtained an image of a metallic asteroid called *Psyche 16.* A flurry of headlines regarding its supposed worth quickly ensued, noting how it put the global economy 'to shame': ~US$10,000 quadrillion compared to US$142 trillion (Jamasmie, 2020). These supposed valuations coupled with plans for interplanetary travel have seen speculations that asteroid mining will become a trillion-dollar market (Jamasmie, 2014), meeting demands from both terrestrial and Outer Space markets. With such headlines, the past decade has seen an increasing involvement from the private sector in all aspects of Outer Space operations – ranging from launch capacities to satellite capabilities, and recently expanding to include manned space launches (Grady, 2017: Luscombe and Sample, 2020). Taken collectively, these private-sector activities comprise the New Space Economy (NSE). The NSE is not limited to current operations; various actors are advocating for a privatised extractive industry to be developed, specifically around asteroid mining (BBC News, 2012: Matloff et al., 2014: Rincon, 2013). These actors are seeking to legitimise asteroid mining efforts not only through the physical and legislative enclosure of Outer Space but through the enclosure of imaginative spaces also. Whilst asteroid mining was touted in the late 1970s and 1980s (McCurdy, 2011), it has returned with increased enthusiasm and traction; several asteroid mining companies having been founded since 2012, beginning with Planetary Resources and DSI and expanding in range since then. Indeed, the range of companies engaging with asteroid mining or supporting technologies now includes DSI (now owned by Bradford Space), Planetary Resources (now owned by ConcenSys), AMC, Aten Engineering, Deltion Innovations Ltd., Kleos Space, Neora, Offworld, Planetoids Mine Company, Spacefab.us, Space Resources Australia, and TransAstra. Advocates of asteroid mining offer a variety of justifications for their proposed endeavours, ranging from an environmental

impetus due to climate change (Matloff et al., 2014) to the ability of asteroid materials to be used as spatial extension resources. The primary impetus, however, is the industry's estimated value. The resources asteroid mining companies seek to extract – broadly grouped as water, industrial metals, platinum group elements, and volatiles – are typically discussed in the trillions and quintillions (see Desjardins, 2016 for some discussion and infographics).

However, despite the enthusiasm of asteroid mining advocates, the proposed extractive industry is not unproblematic. Whilst the narratives surrounding asteroid mining frame this industry's future as something certain – discussed in advertising material, websites, and NSE circles in the affirmative – there are still many unanswered questions. Aside from issues of technological and fiscal viability, uncertainty remains surrounding ownership, land rights, and *whose* future this industry speaks of, for, and mobilises. Due to such uncertainties, actors with vested interests are seeking to enclose the Global Common of Outer Space, 'opening' the 'final frontier' to what some commentators are referring to as a modern Gold Rush (Cofield, 2016: Elvis and Milligan, 2019: Pandya, 2019).

Alongside the increasing range and traction of NSE activities has been an increasing attention to Outer Space from a range of social science perspectives. Whilst studies of Outer Space geopolitics has typically had a military inflection, if not a sole focus, attention has steadily diversified in recent years to encompass a range of disciplines that comprise the Social Studies of Outer Space. Indeed, this area of study has burgeoned in recent years, contributions from the social sciences, humanities, and arts doing much to develop this nascent field (Dunnett et al., 2019: MacDonald, 2007: McCurdy, 2011: Szerszynski, 2019). The social studies of Outer Space has subsequently grown to incorporate a multitude of fields and interests, including (but not limited to): astrosociology (Caroti, 2011: Hearsey and Pass, 2011:

Pass, 2006: 2011); access to Outer Space (Vedda, 2008: Worden and Sponable, 2006); the (human) body in space (Dickens and Ormrod, 2007: Pankhurst and Jeevendrampillai, 2020); Extraterrestrial Intelligence (ETI) (Drake et al., 1993: Harrison, 2011); speculative economies of Outer Space (Dudley-Flores and Gangale, 2012: Harrison, 2000); governance of Outer Space and its environment(s) (Hickman, 2010: 2012: Newlove-Erikksen and Erikksen, 2013); future imaginaries (Coleman and Tutton, 2017: McCurdy, 2011: Messeri, 2016: Tutton, 2017); continuing military debates (Anantatmula, 2013: Mistry and Gopalaswamy, 2012); lunar resources (Alvarez, 2020: Klinger, 2017); the nature of planetary governance (Cockell and Horneck, 2004: Collis, 2017: Collis and Graham, 2009); space weather (Taylor, 2020); the satellite industry and Kessler syndrome (Adilov et al., 2018: Kessler and Cour-Palais, 1978: Kessler et al., 2010); the Mars One Project (Tutton, 2017); terraforming/geoengineering (Fogg, 1998: 2000: McKay et al., 1991); the ethics of space-based research and exploration (Billings, 2006: McArthur and Boran, 2004: Spennemann, 2004); and terrestrial implications of the space industry (Redfield, 2000: Smiles, 2020). These areas culminate in a growing and fertile area that constitutes the Social Studies of Outer Space.

Whilst there has been an increasing range of topics studied under the broad field of the Social Studies of Outer Space, the role and contribution of geography cannot be understated. Indeed, geography has a key role to play within this ever-diversifying field, numerous areas of geographical thought providing fertile ground through which to critically engage with asteroid mining and its attendant debates. The discipline's deliberate and considered approaches to the ongoing environmental crisis, nature-capital relations, capitalism and extraction, and globalisation are all fruitful areas through which to begin critically engaging with asteroid mining. This proposed industry intersects with these geographical literatures due to the wide variety of issues it is purported to solve or intersect with. Advocates propose that asteroid

mining is an answer to the ongoing environmental crisis through its taking extractive and polluting industries off Earth and link asteroid mining to the 'green economy' due to renewable energy sources requiring certain metals that these companies will mine from asteroids. Asteroid mining also raises issues at the heart of geographical inquiry: linking the 'solution' to the environmental crisis to new modes of mining perpetuates a socioeconomic system premised upon expansion, raising questions around capitalism and extractivism that are grounded in social justice.

Through intersecting with issues of a socioeconomic system premised upon expansion, extraction, and their symbiotic relationship with capitalism and its attendant issues, asteroid mining draws us into another area of critical study within geography: (de)colonisation. Whilst mining has a long history that dates back to the paleolithic, with new technologies being introduced by the ancient Greeks and Romans (Healy,1978), extractivism became inextricably bound up with expansionism and capitalism during the fifteenth century colonisation of the 'New World' (Lynch, 2002: McLeod, 2010). This process of colonisation was not simply about subduing the inhabitants of these 'new' lands; it also fundamentally altered human-nature relations and the onto-epistemological framework through which the world is related to and understood. This new set of relations was premised upon a Judeo-Christian ideology: claiming land *for* God wherein it is subdued and subsequently utilised, dominion being actualised through colonial settlers (Wilkes and Hird, 2019). This conception of human-nature relations still underpins capitalist notions of materiality, though instead of land being part of a holy dominion it is now a commodity. Here, the underlying rationale of asteroid mining comes readily into the remit of another dimension of critical geographical inquiry, taking seriously the implications of a colonial history and its influences on the present and future(s). Through questioning the colonial frameworks that subtend capitalism and expansionary extractivism,

geography also asks how we may begin to decolonise these relationships. This process does not simply rely on critically examining the socio-historical legacies that influence a myriad of relationships and power dynamics as they presently exist, but demand that we go about critically (re)imagining futures and their possibilities (Urry, 2016). Here, we may look to Ethnofuturism: an imaginative process that simultaneously engages the *Ethno-* (referring to the archaic, indigenous, or cultural histories of peoples) and *-futurism* (deemed the cosmopolitan, urban, and technological) (Hennoste, 2012: Kolcheva, 2015), creating a temporally hybrid space wherein cultural pasts and speculative futures collide and are blurred. Through combining a myriad of different histories and cultures with various futurities, new sites of socio-political (re)imagining are made possible.

Thus, geography is well positioned to contribute to the burgeoning field of the Social Studies of Outer Space. However, despite the increasingly diverse range of topics and analyses produced through the Social Studies of Outer Space, very little work has been produced relating to asteroid mining. Literature on mining the Outer Space environment has typically focused on lunar mining (see Klinger, 2017 and Alvarez, 2020 for examples) or how to preserve extraplanetary[1] environments and areas of scientific or cultural interest (Cockell and Horneck, 2004: Spennemann, 2004). The rare instances where the literature has turned its focus towards asteroid mining, several issues remain. Firstly, focus on asteroid mining has primarily been driven through industry discussion pieces and media coverage (BBC News, 2012: Rincon, 2013). Indeed, whilst Sommariva (2014: 2015) provides some useful overview of asteroid mining, the arguments they provide to justify asteroid mining have Eurocentric

[1] In this instance, I use 'extraplanetary' to mean outside of Earth's atmosphere. This clarification is added as the context of 'extraplanetary' inevitably shifts depending on the planet being spoken of.

and colonial undertones[2], uncritically support a free-market model for the Outer Space economy[3], and Sommariva's positionality and interests may be construed as suspect[4]. Pieces such as these underscore the need for geography and the Social Studies of Outer Space to critically engage with asteroid mining, providing new analyses and frameworks for the ethical, moral, and justice[5] aspects of Outer Space and extraterrestrial extractivism. Secondly, academic focus has generally approached asteroid mining from a legal policy analysis perspective (such as Fox, 2016: 2019: Stockwell, 2020). Whilst this provides some useful context surrounding asteroid mining, it fails to account for the social, cultural, political, and ethical dimensions of asteroid mining and the wider processes at play[6]. Finally, where the literature has moved away from legal studies to other areas of the social sciences and humanities (Kearnes and van Dooren, 2017), this has been done through a purely theoretical lens. Additionally, these three (limited) areas of literature exploring asteroid mining solely use secondary materials and grey literature[7], leaving a vast amount of material to be gathered and analysed.

Consequently, there remains much to be explored and discussed around asteroid mining within the Social Studies of Outer Space. There is a gap in the literature relating to asteroid mining: the area is under-theorised with Kearnes and van Dooren (2017) providing

[2] Immediately within the abstract, they discuss 'the past opening of new frontiers' (p.82) - problematic terminology unpacked further in this chapter and in chapters 5, 6, and 7.
[3] A *de facto* assumption critiqued throughout this thesis.
[4] Aside from being an economist (rendering their engagement of critical social studies questionable), they are a consultant for private space companies and the director of the SEE Lab – a 'multidisciplinary research lab focused on analysis of the space economy'. Whilst seemingly unproblematic at first, the SEE Lab's sole focus is directed towards finance, providing strategic advice for industrial and financial companies. When the centre discusses advising the public sector, this advice is aimed at 'developing' the space economy further.
[5] By noting this, I do not mean to suggest that there are absolute answers to any of these areas and the questions they pose. They are noted to highlight the problematic nature of uncritically adopting a rigid framework developed through one field.
[6] Such as the (inter)actions of NSE actors, governments, companies, space agencies, etc.
[7] Be this policy documents, figures from investment companies, or government and company publications.

the only rigorous theoretical engagement to date and research involving empirical work having yet to be produced. Given the near-absence of literature from the Social Studies of Outer Space regarding asteroid mining, this research has taken a first step towards addressing this pervasive silence. There are substantive sections of this thesis that take a conceptual inflection to remedy the under-theorisation of asteroid mining and this research has collected and generated empirical data. The result is an empirically-grounded thesis that begins to address this gap.

Given this current dearth of empirically-grounded research concerning asteroid mining, this research has sought to begin addressing this gap in the literature. The broad objective of this research is to explore how asteroid mining is being supported and contested in various ways. More specific questions related to this aim were:

1. How are asteroids – and Outer Space – being framed by NSE actors involved in the nascent asteroid mining sector?
2. What are the issues involved in asteroid mining and how are these (not) being addressed?
3. How are the normative assumptions used in the asteroid mining sector contested through the works of Ethnofuturists?

Using these questions and the above positionings to guide the research process, the thesis has been organised around three 'decenterings' that exploring these questions has allowed. Specifically, these themes are the decentering of capitalism, Eurocentrism, and terracentrism. To explore these questions and subsequent themes, empirical data was generated through a multiple method approach. This approach was comprised of interviews, participant observation, textual analysis, and the use of grey literature. This allowed for a corpus of data

to be generated and also recognises the multi-sited nature of the research 'field', taking note of advice from 'Elite studies': that multiple points of data should be used to generate a more accurate picture. Due to this topic engaging with futurity and an extractive industry that has yet to truly begin, a speculative method was necessarily adopted when exploring this data. This data is brought into conversation with the research's conceptual framework in the following seven chapters. It is important to note here, however, that whilst this thesis explores issues of power and grounds itself in postcolonial and anti-capitalist critiques, it does not explore issues of gender in its analysis. Whilst feminist studies have produced vast quantities of interesting and thought-provoking work and is another area of concern within the critical Social Studies of Outer Space, to include this dimension within the thesis – and, more crucially, to do it justice – would exceed the confines of this work. It would, however, be an interesting and fruitful area for future research.

Chapter 2 briefly explores the 'genealogy' of asteroid mining, tracing the contours of its conceptualisation. It briefly explores this development through three broad areas that have informed the popular and scientific imaginaries of asteroid mining. It turns first to the depiction of asteroids and their mining in Science Fiction and the various tropes this has (re)created. It then moves to look at how some of these themes have been reworked or rethought through scientific and military writings before turning to consider how these tropes and information have been variously (re)shaped by and through the NSE.

Chapter 3 provides the conceptual framework informing this research. It explores the material and imaginative practices linking capital, extraction, and frontier-making. Following this, the socio-political dimension is carried through to consider the implications for the politics of futurity and how this is (re)created and contested by various actors, looking at the

linkages between capitalist extraction, disimagination, and Ethnofuturism. The chapter then finishes with a discussion on terracentrism and some of the implications this bears for the Social Studies of Outer Space and asteroid mining more specifically.

Chapter 4 explores the methodology involved in this research. It opens on a discussion of my positionality, critically reflecting on how my identities of being Welsh and working class have influenced my research interests and how this has informed my approach at times. It then moves on to consider some of the theoretical and practical dimensions of the research process, introducing and discussing the use and potential of a speculative research method when exploring questions of futurity. It then turns to consider the potential to regard Ethnofuturism as a method in itself – having explored its conceptual dimensions in the preceding chapter. Finally, the rest of the chapter discusses the rationale behind adopting a multiple method approach, how this enabled the research to progress, and considers interviews, textual analysis, participant observation, and the use(s) of grey literature in turn.

Chapter 5 is the first of three discussion chapters. It concerns itself with how Outer Space is being conceptually and imaginatively 'opened' to permit extractive activities such as asteroid mining. It begins by exploring how asteroids – and Outer Space more broadly – are being (re)framed as exploitable objects that bear the potential to permit a host of promissory futures. It then goes on to discuss how the NSE and actors operating within it are (re)constructing asteroids and creating narratives around various material groupings found within asteroids, generating and (re)interpreting data to render asteroids provisionally 'knowable'. The chapter rounds off by bringing some of this data into discussion with the idea of terracentrism.

Conversely, chapter 6 turns its attention to the processes by and through which the Outer Space and asteroid 'frontier' is being enclosed. Whilst the preceding chapter has discussed the various means through which asteroids are being 'opened' to exploitation, this chapter looks at how asteroids are being enclosed from a common-pool resource to permit private, capitalist exploitation. It explores how this is being achieved through the developing legal framework that surrounds the nascent industry and the attendant discourses being (re)created to support the commercial exploitation of asteroids: specifically, through a combination of a 'greening' discourse and a discourse of capitalistic opportunity. The chapter then turns to occupy itself with the issues of 'excess' posed by any extractive industry, exploring some of the potential issues that arise through asteroid mining and how these are (not) being addressed.

Chapter 7 is the final discussion chapter. Whilst the previous two discussion chapters have primarily concerned themselves with how private actors are (re)framing asteroid mining, this chapter turns its focus onto the works of Ethnofuturists. It explores how Outer Space and asteroids are being reimagined through work that draws from experiences that are not Eurocentric and that concern themselves – implicitly or explicitly – with challenging *de facto* conceptions of Outer Space futurity. It opens with a discussion on Ethnofuturist reimaginings, exploring how the seemingly hegemonic Eurocentric imaginary of Outer Space futurity is being frustrated, critiqued, and forged anew. It then moves on to consider how Ethnofuturists not only challenge the 'imaginary' but how this has material implications for how asteroids are potentially thought about. It discusses how different temporalities by and through which asteroids become 'known' is suggested, opposing or subverting the popular narratives espoused by NSE actors before moving on to discuss how this can open new avenues of

thought regarding asteroids and how they are engaged with, suggesting different relational onto-epistemologies can be (re)made around asteroids.

Chapter 8 is the concluding chapter. It briefly surmises what has been discussed throughout the course of the thesis before turning to suggest some routes for future research. Having introduced the broad context of this research, the themes it explores, and how the thesis is structured, I turn now to briefly explore the 'genealogy' of asteroid mining.

Chapter 2: A Genealogy of Asteroid Mining

2.1 Introduction

As noted in the previous chapter, there is currently a dearth of research and accompanying literature that focuses on asteroid mining: especially from a critical social science perspective. Consequently, this chapter is designed to offer a broad 'genealogy' of asteroid mining[8]; introducing the reader to key developments in the histories of asteroid mining futures. There have been several key areas by and through which asteroids and their mining have come into the public and scientific imaginary. Specifically, these three areas have been: science fiction writings; scientific and military writings (especially during the Cold War 'space race') and; materials and press releases produced by nascent asteroid mining companies. These three areas have often worked in tandem with one another and share overlapping histories. However, for the sake of a clear narrative around the genealogy of asteroid mining, I will deal

[8] I provide a broad overview as an in-depth discussion would be far too large to fit into the confines of a chapter, there having been many twists and turns throughout the history of asteroid mining, its proposed purposes, and the ends it has been intended to meet.

with each of these areas in turn. Therefore, this chapter is organised into three broad sections: the first section deals with asteroids in science fiction; the second with scientific and military writings on asteroids; and the final section on nascent asteroid mining companies. A concluding fourth section provides some information on the 'practicalities' of asteroids – the distances involved, their compositions, and so on – organised into its own section to avoid repeating this information between sections.

2.2 Science Fiction and Asteroids

The genealogy of asteroid mining has its roots in science fiction writings and the genre has continued to provide an array of imaginaries and discourses of asteroids and their mining that have continuously influenced and informed discussions on the industry's (potential) futures (Stableford and Langford, 2018). Furthermore, these imaginaries have not been limited to influencing discussions of asteroid mining but have (re)created popular conceptions of asteroids themselves: as extraterrestrial curios, existential threats, sites of opportunity, and so on. Indeed, science fiction's ability to influence (re)conceptualisations of the future(s) and technologies has been noted and discussed by a range of academics (Birtchnell and Urry, 2013: Kaku, 2011: Kirby, 2010: Kitchin and Kneale, 2001: Kneale and Kithchin, 2002: Tutton, 2017). However, this should not be construed as a one-way relationship, recognising instead that science fiction writings have often been inspired by – or produced in response to – scientific theories and discoveries. Instead, science fiction and scientific writings should be regarded as a symbiotic relationship: an observation that is pertinent not only within this section but throughout the entire thesis. Considering this, the importance of science fiction to the genealogy of asteroid mining cannot be understated, having played significant roles in the history and development of an array of asteroid-human imaginings. For the sake of

narrative clarity, I will discuss each of these imaginaries in turn. This may create the (false) impression that there is a neat chronology to the development of these tropes. However, their history is much 'messier' than linear writing can convey and the reader is encouraged to keep this in mind throughout this chapter.

George Tucker's *A Voyage to the Moon* (1828) is often cited as the first example of science fiction, his text exploring some of the scientific theories behind manned space travel (albeit in a satirical manner). Tucker's text – whilst focusing on the Moon and space travel – demonstrates the important relationship between scientific theory and the imaginary: the former inspiring the latter. This relationship is important to note as the first science fiction text dealing explicitly with asteroids derived much of its inspiration and rationale from the scientific reasoning of the time. In the early nineteenth century, Heinrich Olbers hypothesised that asteroids were the remnants of a destroyed fifth planet[9]. This proved a foundational inspiration for the first science fiction text to involve asteroids: Robert Cromie's *The Crack of Doom* (1895). In this text, "Phaeton's" destruction is attributed to the misuse of nuclear technology. *The Crack of Doom* marks the beginning of a strand of science fiction that centers itself around human hubris and the bounds of scientific knowledge. Scientific naivety is similarly applied in Gerald Heard's *Reply Paid* (1942), wherein scientists have experimented with matter's makeup, once more leading to the destruction of this fifth planet. These tropes were adopted in later science fiction, advanced technologies causing the destruction of planets such as the *Death Star*'s destruction of *Alderaan* in *Star Wars* (1977). This narrative trope came to hold particular salience within the popular imaginary due to their postulating on the aftermath of nuclear war and unwieldly scientific discoveries; issues embossed on the

[9] Later dubbed 'Phaeton' by J. G. Radlof in 1823 (translated by Anne-Marie de Grazia, 2009).

zeitgeist of the 1950s and 1960s due to the mounting pressure of the Cold War's nuclear arms race. Despite writing in 1895, Cromie's *The Crack of Doom* can now be read as an eerie precursor to the existential threat posed by a nuclear arms reality – a trope and reality that inspired the black comedy *Dr. Strangelove or: How I learned to Stop Worrying and Love the Bomb* (1964).

Shortly after *Dr. Strangelove*, plotlines involving asteroids took a notable shift. Instead of asteroids being the detritus of a destroyed fifth planet or proto-Earth that served as allegorical warnings against Cold War military science, they came to embody existential, world-ending threats in themselves. This trope has been a popular staple of science fiction, being featured in literature (perhaps most notably in Blish and Knight's *A Torrent of Faces* (1967)) and – perhaps most notably – in an array of movies over the past six decades: *The Day the Sky Exploded* (1958), *Meteor* (1979), *Armageddon* (1998), *Deep Impact* (1998), *Impact* (2009), and *Greenland* (2020). Whilst this trope began in the late 1950s with observations that some asteroids pass well within the orbits of Mars and Earth – debunking the idea that Outer Space was empty between the planets and their natural satellites[10] – there has been a notable increase in the number of movies using asteroid impacts as a narrative device since the Alvarez Hypothesis (Alvarez et al., 1980). The Alvarez Hypothesis – that an asteroid impact caused the Cretaceous-Paleogene extinction of dinosaurs – fueled speculative science fiction writers and contributed to an increase in stories using asteroids as harbingers of species extinction.

[10] A belief that saw Eugene Newman Parker's paper proposing the existence of solar flares initially rejected several times before the journal's editor stepped in and allowed the paper to be published as there seemed to be no issues with the calculations. Parker was vindicated several years later when a probe to Mercury accidentally discovered signals from a solar flare.

Science fiction has not only depicted asteroids as a threat to the Earthbound but have frequently been portrayed as obstacles or deadly barriers to space-travelers, littering cosmic highways and impinging upon navigability. Isaac Asimov's *Marooned Off Vesta* (1939) centers around a space traveler becoming marooned in space due to a collision with an 'asteroid' or similar debris and Jack Williamson's *Seetee Shock* (1949) involves an asteroid field so dense that it is impossible to navigate. Later works such as Mark Clifton's *Eight Keys to Eden* (1960) continued to use asteroids as cosmic obstacles to some degree, though with added nuance in response to new scientific information. Although *Eight Keys to Eden* noted the difficulty of navigating asteroid fields due to the need for a microsecond-updated map, it also acknowledged the thin dispersal of asteroids within the asteroid belt and that these obstacles can be overcome through flying over or under the asteroid field[11]. Despite this, asteroid and comet collisions have continued to be used as plot devices throughout Science Fiction, such as in *The Chronicles of Riddick: Pitch Black* (2000).

Throughout the development of these various tropes, a consistent theme of science fiction has been asteroid mining in a variety of guises. Asteroid mining was first featured in Garrett P. Serviss' *Edison's Conquest of Mars*[12] (1898): Edison's armada discovering Martians mining a solid gold asteroid and engaging in battle. Asteroid mining continued to be a staple of science fiction during the first half of the twentieth century, often being deployed as an analogue for 'frontier' goldrushes of the past, such as Clifford D. Simak's *The Asteroid of Gold* (1932) and Stanton A. Coblentz's *The Golden Planetoid* (1935). Asteroid mining has been a consistent trope since its inception in 1898, moving from the confines of literature into a

[11] I take this issue up further in Chapter 6's discussion on asteroid mining and waste.
[12] Not only is Serviss' text the first known science fiction to use asteroid mining, it is also contains the first known science fiction depictions of ray guns (a 'disintegration ray') and space suits.

range of other media: film (such as *Alien* (1979)), television (e.g. *Red Dwarf* (1988-present) and *The Expanse* (2015-present)), and video gaming (e.g. *EVE Online* (2013) and *No Man's Sky* (2016)) all featuring asteroid mining as key plot devices. Indeed, whilst *Armageddon* (1998) uses the asteroid as existential threat trope, mining plays a fundamental role throughout the movie; mining knowledges and technologies providing the means for Earth's salvation. The use of mining knowledges and technologies as a mode of salvation is interesting here as asteroid mining is often invoked or portrayed as such in response to numerous existential crisis facing late-stage capitalism and environmental limits: an area of capital investment and return promising further growth, a response to the environmental crisis that sees a polluting industry move off-planet, an endeavour that enables access to other planets more easily and enables 'back-up colonies' to be created[13], and so on.

Asteroids have been used as sites of extraction in favour of planets in science fiction for numerous reasons. Asteroids have frequently been used as an extractive hinterland or 'wildernesses'[14] – places of uncertainty or murkiness – whereas planets are often 'anchors': cores to the asteroid periphery. This trope of the asteroid 'frontier' – a cognitive 'elsewhere' – has spawned further tropes of asteroids as sites where pirates or cosmic bandits may lurk (e.g. Royal W. Heckman's *Asteroid Pirates* (1938) and Isaac Asimov's *Lucky Star and the Pirates of the Asteroid* (1953)) or where fugitives may hide from the authorities (e.g. *Star Wars: Empire Strikes Back* (1980)). Asteroid mining and the treatment of asteroids as areas of extraction has also seen asteroids develop into dynamic sites that can be used for multiple

[13] An argument that has been advanced by numerous advocates, the premise being that planetary catastrophes that threaten human extinction are inevitable. Therefore, the argument goes that becoming a multi-planetary species would allow humanity to continue if something were to happen to the Earthbound 'colonies'.

[14] Here we may think of the influence early science fiction tropes of 'goldrushes' has had, this wilderness narrative mirroring the idea of the 'Wild West'.

purposes beyond the nefarious, being depicted as space bases (e.g. Robert A. Heinlein's *Misfit* (1939)), pleasure resorts (e.g. Charles Platt's *Garbage World* (1967)), cosmic petrol stations and stores (e.g. *Rick and Morty* (2013-present)), sites that allow for the colonisation of the solar system (e.g. *The Expanse* (2015-present)) or a combination of all these uses (e.g. Kim Stanley Robinson's *2312* (2012)). These tropes – particularly those of asteroid bases and their allowing the continuing colonisation of the solar system – have been adopted, deployed, and utilised by both the scientific community and the NSE sector[15].

Asteroids have provided dynamic sites throughout science fiction's histories. They have – to varying degrees and at various times – provided terrestrial analogies and warnings, been existential threats, obstacles and hazards, extractive sites containing untold riches, clandestine areas that operate as peripheries and wildernesses, and provided bases to continue expansion efforts throughout the solar system. Whilst diverse in their depiction and conceptual uses, these tropes are often drawn upon to varying degrees by both the scientific community and private actors; often being blended together to advance particular agendas within the popular imaginary. It is the scientific and private conceptions of asteroid mining that I now turn to, considering their relation to science fiction tropes and how these have been mobilised to advance various interests.

2.3 Science, the Military, and Asteroids

Whilst the origin of asteroid mining's conception may be located in *Edison's Conquest of Mars* (1898) with science fiction providing multiple developments to its conception through an array of media, the idea(s) of asteroid mining have been similarly shaped via input from the scientific and military-industrial complex. The first four decades of the twentieth century saw

[15] Expanded upon further throughout this Chapter.

discussions of asteroid mining dominated by science fiction writings. However, the Cold War had Outer Space quickly dubbed the fourth domain of war and – with this new designation – the military and military-funded science projects turned increasing attention to Outer Space as a strategic domain. These projects gave rise to a plethora of concepts and ideas, some acted upon and many others 'mothballed'[16]. These strategic developments are not merely consigned to the Cold War 'Space Race'[17] but have continued to be advanced to maintain strategic superiority and operational effectiveness. Examples of such material advances are satellites, the moon landing, the *Mariner* missions to Mercury and Venus, ASAT[18] technologies, and even Landsat and GPS[19]. However, alongside these examples are an array of projects and concepts that failed to materialise. Despite their failure to become tangible realities, these concepts have continued salience in contemporary discussions on asteroid mining and their associated discourses. I will now consider these early ideas, followed by a discussion on contemporary ideas and proposed uses for asteroids and their mining.

Although discussions of asteroid mining were primarily consigned to science fiction during the first half of the twentieth century, the Cold War and the attendant Space Race saw scientists and the military consider numerous Outer Space projects to maintain strategic advantages over their enemies. One such project or theme of discussion were asteroids and their potential uses – for both their own 'side' and to what ends an enemy may use them for. Perhaps the most notable voice on the matter of asteroids and their potential strategic uses was Dandrige Cole. Cole was a strong advocate for what he called 'future studies': the attempt

[16] 'Mothballing' refers to the discontinuation or 'shelving' of a project or program – usually due to the withdrawal of funding.
[17] Arguably defined as ranging from the USSR's launch of *Sputnik I* in 1957 to the USA's moonwalk of 1969.
[18] Anti-Satellite technologies.
[19] Landsat originally launched for US intelligence programs and GPS having been developed for US military uses but access was granted for public use following an executive order in 1985.

to study technological developments and predict their potential uses, allowing for opportunities to be realised and countermeasures prepared[20]. Cole's work on 'future studies' led him to consider the potential uses of asteroids; both the threats and strategic opportunities they posed. Indeed, Cole proposed that asteroids could be weaponised by the USSR, suggesting that the Superpower was on its way to developing technologies that could redirect Near Earth Asteroids (NEOs) to specific, targeted locations on Earth[21]. Whilst Cole's presentation sought to outline the threat asteroids may pose in the hands of hostile foreign powers, it also represents the scientific community's first real foray at engaging asteroids as more than cosmic relics or artifacts; engaging with them instead as dynamic sociable sites of threat and opportunity. Cole continued to consider asteroids and their potentialities in the fourth domain of war, proceeding to suggest that they be strategically used in two distinct ways: as bases after being hollowed out and to be mined for key resources (Cole and Cox, 1964). Once more, whilst science fiction had proffered these ideas (such as bases in Robert A. Heinlein's *Misfit* (1939) and mining in multiple texts), Cole and Cox's (1964) work was the first book on the matter produced by the scientific community, mapping out the benefits posed by such an endeavour. Indeed, Cole was one of the first to note the supposed material worth of asteroids (1963), proposing expeditions to the asteroid belt to extract these materials or bringing an asteroid back to orbit the Earth for mining: both concepts still espoused by asteroid mining advocates to this day.

[20] Something that has come to pass in military planning and 'war games' in which various scenarios are mapped out and potential responses considered and analyses. This process of prediction and prognostication may, in itself, (re)produce certain futures and potential threats and has been analysed by various scholars (Carr, 2010: Holden, 1975: Poo, 2012).

[21] Such a development could be read as a scientific imaginary that combined the scientific advancement and asteroid as existential threat tropes discussed in the preceding section.

Whilst Cole's work proposed that asteroids could be hollowed out and used as extraterrestrial bases (something that features prominently in Kim Stanley Robinson's *2312*), another potential means for creating permanent Outer Space bases and habitats were O'Neill Cylinders (1976). These bases would consist of two cylinders that moved in opposite directions from one another, thus creating artificial gravity within the cylinder (the most notable depiction of an O'Neill Cylinder of late is the 2013 movie *Elysium*). Whilst at first glance O'Neill Cylinders appear to be a significant shift from mining asteroids and using their husks as bases, their proposed use is still rooted in the premise of asteroid mining. Indeed, O'Neill (1976) proposed that these habitats be created from materials mined first from the Lunar surface and, later, from asteroids. Thus, rather than representing a massive divergence from Cole's proposal, O'Neill's work may be considered a refining of Cole's concept instead: both concepts were posited to assist with manned exploration of the solar system and for the strategic advantages they posed, the latter posing a 'sleeker' outcome that allowed for some additional capabilities (e.g. farming areas, lab spaces, etc.). Indeed, both of these models were forwarded for similar outcomes: to increase the reach and scope of manned space travel; to create and maintain a human presence in Outer Space; and to open the solar system up to extraction (as depicted in *The Expanse* (2015-present)).

The overlap of intended outcomes for both Cole and O'Neill's proposals also brings us to a key consideration in the scientific and military pursuit of asteroid mining, specifically: why focus on asteroids instead of planets? Whilst the answer to this question for science fiction was that asteroids could be used as murky hinterlands that advanced plots and produced new sites of imaginings, the answer for the scientific and military communities is far more pragmatic. If one were to mine on a planet, the materials would primarily be used to sustain operations and bases on that planet, a fraction of these materials being exported elsewhere.

Asteroids, on the other hand, have been continuously conceived of as resources that operate as 'gateways' to the rest of the solar system – as spatial extension resources (Buck, 1999). This was the proposed use for asteroids in Cole and O'Neill's works and continues to be the case in contemporary scientific conceptions of asteroid mining and its use(s). Specifically, in contemporary scientific circles asteroid capabilities to 'open' new areas of the solar system to manned exploration takes the form of In-Situ Resource Utilisation (ISRU). ISRU is surmised by ESA as a process that:

> "concerns the exploitation of the lunar or asteroid resources enabling the in-situ supply of materials needed for building habitats and potentially empowering human beings to perform activities in space." (ESA, 2021)

Indeed, NASA have discussed the need to develop ISRU capabilities 'the farther humans go into deep space' to generate required materials (Hall, 2020). These capabilities are something NASA intends to explore on the Lunar surface as part of their *Artemis Program*, exploring what useful materials and fuels they can produce before using these processes on asteroid and Martian regolith to create oxygen, water, and fuel (ibid).

Although asteroid mining is most frequently discussed in relation to ISRU and its ability to extend and maintain manned missions deeper into the solar system, two other distinct purposes have been proposed. The first, more outlandish of these proposals is related to conversations of preventing asteroids colliding with Earth. Asteroid preparedness has frequently been broached over the decades and culminated in NASA's *Asteroid Redirect Mission (ARM)*: an initiative designed to knock an Earth-bound asteroid off course (though this has recently been mothballed through Trump's signing of White House *Space Policy*

Directive 1). Whilst most plans centered around knocking an asteroid onto a new course, some commentators proposed that asteroid mining could be used to simultaneously remove the existential threat and generate massive amounts of resources and attendant profits. The second additional purpose proposed for asteroid mining has been linked to the 'green futures' movement(s). Here asteroid mining is advanced as a mode of 'greening' the extractive sector by moving mining processes and various polluting industries off-planet. This has been perhaps most vociferously advanced by Matloff et al. (2014). In their book *Harvesting Space for a Greener Earth*, they link asteroid mining to the green movement and advocate for asteroid mining in response to climate change[22]. Thus, through linking the 'need' for asteroid mining to overcoming climate change, the project becomes fundamentally linked to responding to an existential threat once more.

Asteroid mining, therefore, has a fairly long history within the scientific and military communities, spanning six decades and having several intended purposes. Whilst initial proposals posited the use of asteroids as bases – whether following Cole's conception or the O'Neill model – this focus has shifted somewhat in recent years. Now, rather than being bases in their own right, asteroids are often regarded as 'gateways' to be used for ISRU, enabling manned missions to travel further into the solar system for longer periods of time. Whilst this is the most popular conception for the use of asteroid mining, advocates have also suggested that asteroid mining be used to remove Earth-threatening asteroids and as a response to climate change: removing extractive and polluting industries from the Earth. Whilst some of these proposed uses of asteroid mining have been more readily advanced than others, all

[22] Though a rebuttal may be that it would cost much less to stop causing such a mess in the first place.

have been utilised by private asteroid mining actors to varying degrees. It is these private interests I now turn to discuss.

2.4 The New Space Economy, Asteroids, and Mining

The third and final area wherein asteroid mining's history and accompanying narrative(s) has been shaped is the private sector. Whilst science fiction did much to advance early asteroid mining imaginaries and the scientific/military community built upon these or created alternative conceptions, private companies and their respective interests have been brought to bear upon the space industry: beginning in the 1980s and increasing significantly over the past decade. Indeed, although asteroid mining was initially discussed by the scientific/military community throughout the 1960s and 1970s – firstly by Cole with alternative conceptions posited by O'Neill – private interests in extraterrestrial mining were not seriously voiced until the 1980s. Interest began with Gerald Kulcinski suggesting that Lunar regolith be mined for Helium-3, for use in nuclear fusion. This suggestion caused some speculative projects to be proposed, though these failed to come to fruition (McCurdy, 2011).

Instead, private interests in asteroid mining would have to wait nearly three decades for serious conversations to be had. This renewed and reinvigorated discussion came in 2012 with the announcement of two asteroid mining companies: Planetary Resources[23] and Deep Space Industries[24] (DSI)[25] (BBC News, 2012: Rincon, 2013). These private interests have sought to capitalise on the space industry's desire to procure materials in Outer Space; in part to

[23] Now owned by ConsenSys.
[24] Now owned by Bradford Space Industries.
[25] Since their founding, a number of other companies have been set up either with the aim of asteroid mining or to facilitate various aspects of proposed operations. Some of these companies include: AMC, Aten Engineering, Deltion Innovations Ltd, Kleos Space, Neora, Offworld, Planetoids Mine Company, Spacefab.us, Space Resources Australia, TransAstra.

reduce the costs of various missions[26] and to provide key materials for these missions also. Given that the private sector has watched the space industry's development and has sought to meet the industry's needs through increasing Public-Private Partnerships (PPPs), it is hardly surprising that the private sector should parallel its mining ambitions on asteroids in favour of planets. However, alongside the reasons given by the scientific community in its discussions on ISRU, the private sector has produced its own set of reasons for pursuing planetoids over planets. Their reasons include: accessible orbits with near-Earth passes; low gravitational masses reducing fuel consumption; a wider range of resources being present; and water being 'readily extractable' (see Figure 5.2 for more detail). However, the most likely reason for this focus is due to the perceived market for these materials, there being an increasing number of manned missions planned for Mars.

Private asteroid mining firms have keenly mobilised imaginaries that were first posited in science fiction – from their images of asteroid bases and mining operations to the trope of a new 'frontier' goldrush – and have similarly seized upon arguments made within the scientific community; especially the argument of 'greening' extraction through moving it off-world. Indeed, these supposed merits of asteroid mining have been advanced by private companies through multiple media over the past decade with claims ranging from preventing Earth's ecological decline to promises of a 'trillion dollar industry'. All these claims are premised upon the purported abundance of minerals contained within asteroids. Minerals most often cited in reports and discussions of asteroid mining include but are not limited to: water; iron; nickel; and platinum group elements. Each of these material groupings have different imagined uses[27] that are mobilised by private actors to simultaneously advance their interests and

[26] A major impetus behind reusable rockets such as those being produced by SpaceX.
[27] Expanded upon in detail in Chapter 5.

make their purported futures more tangible and 'felt' in the present. Indeed, the inherently speculative nature of asteroid mining is something that the sector has used to its advantage: speculating on the abundance of resources fuels the asteroid mining dream whilst simultaneously fuelling speculation on the value and markets of these minerals themselves[28]. This speculation goes beyond the resources earmarked for extraction and is applied to asteroid mining itself, there being different conceptions of how asteroid mining may look and the processes involved. This has enabled different companies to fill various niches within the asteroid mining sector. The result has been a group of companies that are 'competing' with one another whilst occupying different areas of the industry with diverse focuses: so 'competing' in a vast yet sparsely populated field. Whilst the most popular conception of asteroid mining is 'grabbing' an asteroid[29], grinding it down, and sorting materials into their various groupings, several other methods have been proposed. These include but are not limited to: surface mining; shaft mining; using magnetic mining to strip loose metallic minerals from the surface of asteroids; self-replicating machines[30]; and, most recently, biomining[31] (Dunbar, 2020).

Despite the speculative nature surrounding much of asteroid mining's imagined futures, this has not prevented the sector having tangible impacts. These influences are most notable in national legislations in numerous countries – of which asteroid mining companies claim to have influenced through lobbying to varying degrees[32]. Such policies include the *U.S. Commercial Space Launch Competitiveness Act* (2015), *U.S. Space Directive-1* (2017), U.S.

[28] This topic is taken up and explored further in Chapter 5.
[29] Where a spacecraft attaches itself to an asteroid and anchors itself there for the mining process.
[30] One of the more outlandish proposals.
[31] The feasibility of this is currently being tested in the ISS lab.
[32] These claims have been made at conferences attended as part of this research and on DSI and Planetary Resources websites (no longer accessible).

executive order *"Encouraging International Support for the Recovery and Use of Space Resources*" (2020), Luxembourg's *Space Law* (2017), the *U.K. Space Industry Act* (2018), and draft legislation currently being debated in India to name a few. This legislative wrangling and lobbying have not been uncontentious, opposition often being voiced due to Outer Space being a Global Common and, consequently, having the common heritage principal applied. However, asteroid mining advocates have sought to rebut and stifle this opposition through employing means typical of their terrestrial counterparts. Specifically, they have co-opted the notion of the common heritage principal to justify their hopes of exploiting asteroids and stripping them of their 'resources'. Whilst advocates of the commons principal posit that no individual may enclose or lay claim to a common, mining advocates have argued that the 'benefits' derived from extraction will be shared by all, therefore allowing all to benefit from their 'common heritage' (Steinberg, 2018). Some have attempted to rebut this perversion of the common heritage principal by arguing that the Global Commons also belong to future generations (Buck, 1999: Steinberg, 2018). However, private interests argue that the benefits of extraction will 'trickle down' through the generations at best or regard future generations as 'externalities' at worst (Steinberg, 2018). Asteroid mining advocates have taken this further to argue that disallowing their industry would be to deprive humanity of its 'destiny' of becoming a multiplanetary species[33].

2.5 The 'Practicalities' of Asteroid Mining

Having discussed the genealogies of asteroid mining's conceptualisation through science fiction, scientific and military writings, and the nascent asteroid mining industry, I now

[33] These arguments often invoke the idea of manifest destiny – drawing upon colonial histories and the ideas in early science fiction of extraterrestial goldrushes based upon 'frontier' histories.

turn to discuss some of the 'practicalities' of asteroid mining. Specifically, I turn away from discussions of how asteroid mining has been perceived and portrayed, looking towards what asteroids are, their various compositions, the distances involved, and so on. Whilst some of the debates over how asteroids should be utilised differ – whether they should be appropriated as profitable points of extraction, as spatial extension resources for manned explorations, or to reduce the costs of interplanetary travel – this section briefly discusses the materialities of asteroids themselves. This topic is pertinent to both scientific and extractive missions to asteroids, meaning that much of this information would have been repeated between sections 2.3 and 2.4. With this in mind, the material dimensions of asteroid mining have been placed in this section instead.

As noted during the discussion of science fiction, asteroids were once thought to be the remains of a planet that had been destroyed by some cataclysmic event, inspiring texts such as *The Crack of Doom* and *Reply Paid*. However, this theory was subsequently rejected for a model wherein the asteroid belt became the result of Jupiter's gravitational mass disrupting the formation of another planet and 'flinging' up to 99% of the material to the outer edges of the solar system. Whilst this has been accepted for some time now, new modelling has suggested that the area that comprises the asteroid belt may have originally been empty, Jupiter's gravitational mass having deposited asteroids *into* the belt (Raymond and Izidoro, 2017). Whether we subscribe to the theory that Jupiter flung material out of the asteroid belt or assisted in depositing material into this area, the interplanetary forces at play are important in this work for two key reasons[34]. Firstly, whilst Davis (1996) has noted the

[34] This also highlights the complexity that a many-bodied system poses and how this may confound understanding and predictability. I return to this topic at several points throughout the thesis, particularly during the conceptual framework and chapter 5's discussion.

importance of considering the impacts asteroids have on geological formation and planetary forces, the case of Jupiter and the asteroid belt highlights that the inverse is true also: that (inter)planetary forces are crucial to our understanding asteroid formation and their geologies[35]. Secondly, Jupiter's influence has – one way or another – 'filtered' the distribution of asteroids, carbonate (c-class) asteroids being found in the 'outer solar system' amongst planets of similar compositions, and silicate (s-class)[36] asteroids being found throughout the 'inner solar system', once more amongst planets of similar compositions. With Jupiter's gravity having operated as a giant filtering system for asteroids, silicate (s-class) asteroids are the dominant asteroid type found throughout the inner solar system and it is these asteroids that are currently the object(s) of desire for various interested actors. Having noted the reasons behind the distribution of asteroids throughout the solar system, the rest of this section concerns itself with the composition(s) of asteroids, how they are classified by different actors, and the distances involved.

Broadly speaking, asteroids are small, rocky objects that orbit the sun and are comprised of particulate matter that failed to be incorporated into planets during the formation of the solar system (Erickson, 2019). Due to their gravitational masses being far lesser than those of planets, asteroids lack a spherical structure, being angular and jagged in shape and range in size from the Dwarf Planet-sized Ceres to asteroids the size of a pebble (Erickson, 2019: Glaze et al., 2018). The composition of these asteroids vary and there is a history of people attempting to create a taxonomic system for asteroids. Chapman et al.

[35] I place 'inner' and 'outer' solar system in inverted commas here to highlight the arbitrary nature of this boundary (as, indeed, is the case with most boundaries). The distinguishing boundary feature here is the asteroid belt itself: the area that lies towards the sun is the 'inner' solar system and the area 'beyond' the asteroid belt is the 'outer solar system. The asteroid belt itself lies between Mars and Jupiter and also operates as a boundary marker between the 'rocky' planets of the inner solar system and the gas planets of the outer solar system.

[36] I return to discussions on the asteroid classification system shortly.

(1975) were the first to make a serious attempt at a taxonomy of asteroids, using a combination of colour, surface albedo, and spectral shape[37]. Although there have been various attempts to 'fine tune' Chapman et al.'s classification system[38], much of the literature still uses their nomenclature or structures derived from their work. This system has been used to classify asteroids as either carbonaceous (C-type/class), silicaceous (S-type/class), or U-types for those that fail to fit neatly into C- or S-types. This classification system has diversified somewhat since its inception to include X-type asteroids (various degrees of metallic and stony composition) and M-type asteroids that are predominantly nickel-iron composites[39]. The use of spectral data has been adopted by asteroid mining companies to identify 'high value targets' for their respective operations, this data being used to identify asteroids that are 'rich' in 'high value resources'. Consequently, extractive industries have produced their own means of classifying asteroids that ranks them by abundance of four desirable material groupings: water, 'volatiles', industrial group metals, and platinum group metals[40]. The relative abundance of these desirable materials informs a classification system that is predicated upon the capitalist calculus: the most 'resource rich' asteroids being ranked higher due to the greater potential return on investment. Consequently, it is the larger and more 'resource rich' asteroids that are targeted by asteroid mining companies. However, whilst the majority of asteroids within the solar system reside in the asteroid belt between Mars and Jupiter, asteroid mining ventures are focusing their efforts on Near Earth Objects (NEOs). This focus on NEOs at the current expense of the more densely populated asteroid belt stems from

[37] Here, spectral shape refers to the spectral line created by the reflection or absorption of particular light frequencies by elements. This information can be used to infer the chemical composition of asteroids and even exoplanets.
[38] Such as Tholen's (1989) work.
[39] The breaking up of these asteroids is though to be the source of iron meteorites.
[40] A more detailed discussion of these material groupings and their place(s) within the asteroid mining sector takes place in Chapter 5.

the mutually reinforcing limitations posed by the state of current technology[41] and the financial outlay required for such a project.

To contextualise the difference in both spatial and temporal terms, an NEO is an object within 1.3 Astronomical Units (AUs) of Earth, which is ~120.9 million miles (CNEOS, 2019)[42]. The asteroid belt, however, is between 2.2 and 3.2 AUs from Earth (~204.6 – 654.72 million miles) (Williams, 2016). The difference between the two means that conducting any mission to the asteroid belt would between 1.69 and 2.46 times greater in both distance and the time taken than that required for a mining mission at the upper limits of NEO distances. Although a distance of 1.3 AUs may still seem like a vast distance, it is close in the context of the solar system, Neptune being ~29AUs from Earth, for example (McClure, 2017). With their being relatively close in the context of the solar system and nearly half the distance away than the asteroid belt, NEOs are often cited as prime sites for extraterrestrial extraction[43]. Indeed, 1.3 AUs is the upper threshold of an NEO, there being many asteroids that travel much closer to Earth, such as Ryugu that has been visited by JAXA at 187 miles from Earth (McCurry, 2019). However, although very close to Earth, upon completion the mission will have lasted six years (ibid), highlighting once more the relatively long time horizons at play when engaging with, and theorising, asteroid mining (we may note, however, that Ryugu was a scientific mission that required far more precision than plans for asteroid mining, wherein the whole asteroid is excavated rather than samples collected and returned to Earth. This would likely reduce the time horizon of asteroid mining missions significantly).

[41] Asteroid mining technologies are still being developed to make these projects viable.
[42] 1AU is equal to the mean distance between the Earth and the Sun over the course of a year.
[43] This point was made during multiple conference talks during the participant observation and through DSI and Planetary Resources website material that I collected for analysis.

The varying compositions and dimensions of asteroids and the respective desirability of the materials they contain results in large fluctuations in speculative valuations and potential profitability. With this in mind, some companies have sought to estimate the abundance of desirable resources such as water on different asteroids to inform their selection process when considering which asteroids to target for mining: this mechanism operating to attempt maximum profitability in the cost-benefit analysis applied. However, the vastly different sizes and compositions posed by asteroids means that their respective valuations can fluctuate wildly, something neatly depicted in Figure 5.3. Whilst these valuations can differ vastly from one asteroid to another, this complexity is something that is capitalised upon by asteroid mining advocates – large value asteroids often producing media-grabbing headlines. This is something that is considered in greater detail in Chapter 5. I will now turn to outline the conceptual framework used in this work.

Chapter 3: Conceptual Framework

3.1 Introduction

Having broadly introduced asteroid mining and the overall aims of the thesis, this chapter provides an overview of the conceptual framework: introducing the concepts that have informed and driven this work. The chapter has been organised into three main sections, each of which brings its own understanding and lens to a critical engagement with asteroid mining and its attendant future(s). These three sections focus on 'Capital, Extraction, and Frontier-Making'; 'Capitalist Extraction, Disimagination, and Ethnofuturism'; and 'The Terracentric Turn'. Each aspect brings with it its own set of provocations, producing numerous (re)readings of asteroid mining futurity that elude simplistic, straightforward analysis. Rather, these three areas offer critiques that serve to decenter *a priori* assumptions of extractivism *vis-à-vis* asteroid mining. Whist these three sections produce their own critiques and provocations of extraterrestrial extractivism, they share between them an overlap wherein both the imaginary and the material are challenged. This creates a site wherein asteroid mining futurity becomes a dynamic topic that is unsettled, debatable, and open to reimagining.

3.2 Capital, Extraction, and Frontier-Making

Of the three areas outlined above, I turn first to consider the relationship between capitalism and extraction. Rather than taking these two terms as separate, I take them to be co-constitutive of one another: capitalism driving the processes of extractivism and vice versa. This symbiotic relationship is fuelled by – and perpetuates – the (re)creation of new 'frontiers'[44] that produce new spatio-temporal fixes for capital and open material resources up for exploitation. This section will focus on the co-constitutive nature(s) of extraction and

[44] Placed in inverted commas here as it is a complex term that will be unpacked in later sections.

capitalism, followed by brief explorations on how frontiers are (re)made. Finally, this section will consider the inevitable 'aftermath' of extraction that is the dynamic issue of waste.

3.2.1 Extractivism and Capitalism: Co-Becoming

Whilst there are numerous modes of extraction that focus on different resources – be they of wood, crops, capital, or even people – I focus here specifically upon mining. Mining bears considerable salience for the social studies of asteroid mining; not simply due to the focus on mining itself but also due its long historical entanglement with the development(s) and trajectories of capitalism (Braudel, 1982: Lynch, 2002). Moreover, these entwined processes have operated together to drive the search for – and exploration of – new 'frontiers' (Bridge, 2000: 2004). Given the salience of mining and the intrinsic link between extractivism and capitalism, I will provide a broad overview of mining's developments, how extractivism and capitalism have become inextricably bound to one another, and how this relates to asteroid mining.

Mining is concerned with the location and extraction of minerals[45]. Minerals can be found in one of two states: either native – where the mineral is found in deposits on its own – or, more commonly, as an ore, where the desired mineral exists in a compound (Healy, 1978: Lynch, 2002: Mumford, 1934). Early miners[46] exploited placers or veins that outcropped at the surface due to the ease with which they could be extracted (Healy, 1978). As these sources became exhausted, early miners were forced to turn to underground mining (ibid). This marks the beginning of the inevitable depletion created by the extractive industry's

[45] Which is to be differentiated from quarrying, where the object of extraction is rock.

[46] Here, we may take 'early miners' to mean a number of peoples throughout history. However, whilst mining can be traced back to the palaeolithic period (the Ngwenya mine in Swaziland being the oldest mine uncovered), here I take 'early miners' to be located during the Greek/Roman/Egyptian periods due to the processes of increasing mechanisation that these miners ended up using.

’ecological contradictions’ (Bridge, 2000: Patel and Moore, 2017) that resulted in Mumford (1934) referring to mining as a ’robber industry’. This was the start of the mining industry’s history with the search for new ’frontiers’; the first ’frontier’ arguably being the subsurface through mining’s increasing engagement with verticality. Indeed, as Nef notes in relation to the value and allure of the subsurface on the development of contemporary society:

> “Early in the seventeenth century Bacon and Descartes dreamed of a paradise of material plenty. Without the treasures of the subsoil and the attraction they exercised on men’s minds, these dreams would have hardly approached fulfilment at the beginning of the 20th century.” (1964; p.4)

These ‘treasures of the subsoil’ and the ‘attraction they exercised on men’s mind’ have led to the ever-increasing depths being travelled by the extractive industries and the inevitable depletion resulting in decreasing grades to be deemed desirable (Braudel, 1982: Bridge, 2000: 2004: 2013: Lynch, 2002: Nef, 1964).

Through penetrating deeper into the Earth’s crust – or the subsurface ‘frontier’ - miners had to learn to separate minerals from new compounds, surface ores tending to be oxides or carbonates, deeper ores sulphides and arsenous compounds (Healy, 1978). The former could be relatively easily treated in primitive furnaces, whereas the latter required further developments in furnace technologies (Healy, 1978: Lynch, 2002: Nef, 2004). These new chemical compositions, coupled with the increasingly complex nature of mining due to its new depths, required new and ever-more sophisticated technologies to be produced.

Increasing technological sophistication incurred a series of extra financial outlay and, consequently, created debates around the governance of mining (Braudel, 1982: Bridge, 2004: Healy, 1978: Lynch, 2002: Mumford, 1934: Nef, 1964), increasing financial outlay shifting mine ownership from unionised workers to wealthy overlords.

With the cost of the technologies to retain mining's viability necessitating the involvement of wealthy merchants and financiers (Nef, 1964), the industry can be said to have undergone a mode of privatisation[47]. It is at this point in mining's history that we may locate the origins of its stringent and now-inseparable relation to capitalism (Braudel, 1982). Given this, we may wish to consider whether it is accurate to say that capitalism drove the exploitation of the 'New World' (Potter et al., 2008) or if it was, in fact, extractivism; the need to locate and exploit mineralogical deposits driving Europeans into new 'frontiers'. In truth, it is neither wholly one or the other: capitalism and extractivism are inseparable, their long and overlapping histories culminating in a symbiotic relationship, each driving the other. Indeed, this point was driven home poignantly when William of Orange took the British throne in 1689 and ushered in a series of reforms, claiming mining to be a 'key driver of growth' (Lynch, 2002), highlighting extractivism's place at the heart of commerce and its perpetually growing financialisation and associated 'returns'.

The search for new mineralogical deposits and capitalism's need for perpetual growth have led to the search for – and opening and enclosure of – various 'frontiers'. Indeed, the depletion of terrestrial mines and the ever-diminishing grade qualities required to maintain viability have led private mining companies to take an interest in 'frontiers' beyond the 'terrestrocentric' (Dalby, 2007); expanding their remits to the sea floor (Childs, 2019: Dalby,

[47] As defined within the context of its time.

2007: Steinberg, 2018) and Outer Space. Both of these areas pose new extractive 'frontiers' for the mining industry to exploit and perpetuate their aims of capital accumulation; they provide mineral deposits for capital to be invested in (Bridge, 2000), better grade qualities than depleted terrestrial mines, and offer spatial fixes for capital (Harvey, 1991) through both the physical spaces where mining is set to take place and through the technologies required to make these endeavours possible. These technologies can also be capitalised upon further through their development operating as a spatial fix for capital themselves and through their producing 'spin off' technologies that can be patented and sold[48], (re)producing capital before extraction even begins. These technologies do not simply 'open' the 'frontiers' to extractive exploitation but become sites of political deliberation themselves and add their own dynamics to the differential relations that constitute socio-political relations to, with, and of the asteroid 'frontier'[49] (Braun and Whatmore, 2010). With this in mind, I will now consider how frontiers are (re)created and some of the specificities therein.

3.2.2 Capitalism and (Re)Making the Frontier

Having considered the inextricable link(s) between extractivism and capitalism – each having driven the other through a symbiotic relationship – I turn now to briefly explore a fundamental aspect of this relationship that assists in the perpetuation of the extractivism-capitalism rationale: frontiers. Whilst often discussed in a normative sense[50], the (re)creation of frontiers is foundational to establishing new spatio-temporal fixes for capital, new resources, and attendant profits (Harvey, 1991: Jessop, 2006: Richardson and Weszkalnys,

[48] 'Spin off' technologies have often been used by national space agencies to justify the levels of funding they receive (usually coming to the fore when their respective budgets come under attack) (See ESA (2020) and Lockney (2020) for examples).
[49] This and the capital accumulation derived through 'spin off' technology are discussed further in Chapter 5.
[50] That is, in a manner that favours a particular established attitude or belief (or attempts to make an attitude or belief the 'norm').

2014). However, new frontiers do not simply appear of their own volition but are (re)created and maintained through a series of discursive practices that play out over and through both material and imaginative media. Furthermore, the domains wherein new frontiers may be formed are not limited to the material but are (re)created over and through imaginative frontiers also (Bridge, 2004: Li, 2014). This has been – and is – the case *vis-à-vis* the New Space Economy and accompanying discussions of asteroid mining.

Outer Space has often been referred to as the 'final frontier'; whether this is in popular culture such as *Star Trek* or through industry promotions such as those released by DSI and Planetary Resources[51] (Doshi, 2016: Feinman, 2014). Whilst this phraseology may be attributed to a socio-cultural imaginary that is grounded in a white, settler colonial positionality, it is also symptomatic of the extractive-capitalistic relations that are being created – and strengthened – to take place within Outer Space[52]. Indeed, late-stage capitalism's perpetual crises (Jameson, 1991) and need for spatial fixes (Harvey, 1991: MacKinnon and Cumbers, 2011), coupled with the increasing depths and complexities of mining[53], its 'ecological contradictions' (Bridge, 2000), and the industry's search for new 'bonanzas' (Bridge, 2010), have resulted in mining companies and interested parties venturing into what they refer to as new 'frontiers' (Valdivia, 2008). These include 'sky mining' for environmentally sustainable diamonds (Ambrose, 2020: Skymining, 2019), looking

[51] These companies have frequently discussed 'industrialising the final frontier' in various promotions over the years.
[52] We should note here that extractive capitalism is bound up within white settler colonialism (Bhabha and Comaroff, 2002: Bush, 2006: Hesse, 2002: Wilkes and Hird, 2019). The reason this is noted separately here, however, is due to the extractive-capitalistic relations operating through different – though often overlapping – means than white settler colonialism alone.
[53] And diminishing grade qualities.

towards the sea floor for new mineral deposits (Childs, 2019: Dalby, 2007), and asteroid mining.

These 'frontiers' are (re)created in response to the (perceived) scarcity of key resources; this 'scarcity' forcing new and reconstituted relations to/with materials and areas to arise (Richardson and Weszkalnys, 2014). Indeed, this state of affairs has led to states and corporations 'redoubl[ing] efforts to extract conventional and unconventional resources in an attempt to deliver ongoing prosperity to citizens and shareholders' (ibid; p.5). This redoubling of efforts leads to the (re)creation of new, and hitherto unexplored, frontiers. However, just as materials and their social relations are constituted through both the materials themselves and the imaginaries and cultural practices surrounding them (Bakker and Bridge, 2006: Bridge, 2004: 2009: 2014), so too can this be said of frontiers (Li, 2014: Steinberg, 2018: Tsing, 2003). Consequently, 'frontiers' are not merely constituted of geographical spaces but are similarly (re)shaped through the socio-political 'frontiers' of imagination, regulation, and ethics also[54] (Steinberg, 2018). Thus, the 'frontier' is a site of simultaneous opening and closing (ibid): the 'closing' of one frontier leading to the 'opening' of another (e.g. 'closing' the frontier as a common 'opens' it for exploitation).

These imaginative, regulatory, and ethical 'frontiers' are by no means immaterial, but pose serious implications for how the material, political, and social dimensions of extractivism are played out. The imaginative frontier is a site where an area's possible uses are first conceived or curtailed. The ethical frontier determines – in part – what is deemed permissible. The regulatory frontier is where these debates become more 'concrete'; issues of land tenure

[54] These areas – especially those of the imaginary and regulatory – are expanded upon further throughout the course of this thesis.

and ownership are thrashed out, taking on significance through its ability to greatly influence influxes of capital into mineral deposits (Bridge, 2004). This then operates as a regime of exclusion whereby legitimate and illegitimate forms of use and abuse come to be differentiated, inscribing boundaries through physical (e.g., fences and landmarks) or discursive means (e.g., title deeds, laws, zones, regulations, and story-lines) (Li, 2014). Through the various 'openings' and 'closings' of these frontiers, actors do not only seek to (re)create exclusionary boundaries but seek to position the 'frontier' (wherever it may be) as a site of 'bountiful emptiness' that is ripe for appropriation through a *terra nullius* argumentation (Buck, 1999: Li, 2014).

A provocation against the enclosure and privatisation of these 'frontiers' - including Outer Space – is the 'common heritage' principal. Outer Space is deemed one of the Global Commons (Buck, 1999) and 'the common heritage of all [hu]mankind'[55], meaning some contend that Outer Space should be exempt from privatisation or enclosure. However, the common heritage principal has been co-opted by businesses to justify their perpetual search for capital accumulation. Where the former posits that no individual may enclose or lay claim to a common, the latter argues that the 'benefits' derived from extraction will be shared by all, therefore allowing all to benefit from their 'common heritage' (Steinberg, 2018). Some have attempted to rebut this perversion of the common heritage principal by arguing that the Global Commons also belong to future generations (Buck, 1999: Steinberg, 2018). However, private interests argue that the benefits of extraction will 'trickle down' through the generations at best or regard future generations as 'externalities' at worst (Steinberg, 2018).

[55] According to the UNOST, though the meaning and intent behind this treaty is now being heavily contested due to the increasing number of state and non-state actors looking to engage in asteroid mining and other off-world extractive industries.

This co-option of the 'common heritage' principal is a site wherein and whereby the 'frontier' is conceptually enclosed as capitalist interests seek to replace a variety of onto-epistemologies with the rationales of capitalist expansion (Tsing, 2003)[56].

A final point to note regarding the 'frontier' is that whilst the 'opening' and 'closing' of various frontiers and the expansionary logics this entails are doubtlessly important to understanding the process(es) of enclosure (Li, 2014: Redclift, 2006: Steinberg, 2018: Tsing, 2003), a crucial point is missing from analyses thus far. Specifically, whilst the materialities and imaginaries of the frontier make it attractive, the 'frontier' simultaneously operates as a site of invisibility. Through being both spatially and temporally distant, the frontier is not only a site of 'bountiful emptiness' (Li, 2014) but is engaged as a site of invisibility where numerous (inter)actions can be played out – both imaginatively and materially. This invisibleness allows for narratives to be (re)created around materials known to be in the 'frontier' and various processes and issues to be omitted (such as waste). This invisibility also enables speculation to occur, that which is known operating in conjunction with what is unknown, perpetuating capitalistic frontierism further. This invisibility enables a variety of imaginative frontiers to be (re)created, maintained, and challenged that then (re)produce socio-material relations and the material frontiers these permit through both physical and discursive means (Bridge, 2004: Li, 2014). This invisibility and the attendant conceptual debates allow for certain issues to be omitted or silenced from discussion. Typically, the main issue disregarded in extractive debates and the (re)imagining of any 'frontier' is that of waste and its subsequent 'afterlife'. It is the issues of waste that I now turn to.

[56] The conceptual curtailing or erasure of the Common Heritage principal is also the partial result of the disimagination process, which is discussed in greater detail later in this chapter.

3.2.3 Extractivism and the Inevitability of Waste (Mis)Management

Having considered the co-constitutive extractivism-capitalism relationship and the fundamental role played by and through the (re)creation of frontiers, I now turn to consider the frequently overlooked issue of extractivism: waste (Bardi, 2013). Indeed, waste is an inevitable outcome of an extractive process, no matter how high a grade quality may be; by definition, a mine with a 10% grade quality is 90% waste. This has led Navin to contend that mining is primarily a waste removal business (Navin in Bridge, 2000). However, the resounding silence on the matter has been increasingly broached over the past decade or so; new geographies of waste beginning to interrogate what waste is, along with how, why, and to whom it matters (Gregson and Crang, 2010). Engaging with these provocations allows us to expose the dynamic nature of waste and uncover a range of socio-political deliberations and sense (un)making involved in the relationships to and with waste (Hird, 2015: Millington and Lawhon, 2019: Moore, 2012: Reno, 2015). Given that waste is an inevitable consequent of mining (Bridge, 2000) – no matter its setting – it is prudent that work studying extractivism accounts for waste in its research and engages with this dynamic (im)material discard.

Recent literature has begun looking at waste as more than 'matter out of place', coming to consider how it is, in fact, 'inseparable from the production of spatial relationships at various scales' (Reno, 2015; p.564). Through regarding waste as more than simple discard and interrogating how it (re)shapes spatial and socio-political relationships at different scales, multiple understandings of what waste is have been produced (Millington and Lawhon, 2019: Moore, 2012). Indeed, Moore has identified at least 12 understandings of waste. According to their analysis waste may be regarded as: a hazard; a resource; a (non-Marxian) commodity: a manageable object[57]; an archive; disorder and matter out of place; filth; a risk; a fetish; a

[57] We may add 'unmanageable object' here also.

governable object; an actant; and as abject (2012; pp.783-92). Furthermore, given extractive capitalism's long and intricate relationship with colonialism – continued through modern land-grabbing by various EuroAmerican corporations throughout the world (Broughton, 2013) – waste becomes a symptom of colonialism that cannot be fully understood independent of both historical and ongoing forms of colonialism (Hird and Zahara 2017; Liboiron 2018: Wilkes and Hird, 2019). Moore's (2012) different understandings of waste and the recognition that waste is a symptom of extractive capitalism's (neo)colonial history and present reinvigorate ideas of what waste is and how, why, and to whom this matters.

These multiple and shifting understandings of waste do not only (re)produce spatial relationships at various scales (Reno, 2015) but also generate multiple temporalities and attendant relationships (van Wyck, 2005). These temporal relationships arise due to the longevity – or 'deeptime horizons' - of waste materials; waste never truly 'leaves', is never fully contained or controlled (Hird, 2013). Given this, risk can be regarded as inevitably bound up in the generation of waste (Kirsch, 2014), producing sites of uncertainty (Metuzals and Hird, 2018). Indeed, waste does not have to be poisonous or reactive to pose a risk, sheer volume alone being sufficient[58] (Bardi, 2013). Consequently, waste can become a source of slow violence for communities and presents various 'species of trouble' depending upon what it is (Erikson, 1994: Nixon, 2011: van Wyck, 2005). Given the multiple and variegated time horizons through which waste can operate over and through, an insidious and inauspicious relationship to waste(s) is produced that culminates in "a state whereby our only solution for dealing with the toxicity our relentless consumption and planetary depletion generates is by producing permanently temporary waste deposits for imagined futures to solve" (Hird, 2015;

[58] We may think here of Aberfan as a case in point.

p.189). Hird (n.d.) has gone on to argue that the Anthropocene marks an epoch wherein these 'permanently temporary waste deposits' are left for imagined futures to solve. This is (re)produced through a rationale of 'develop now, remediate later' that incurs steep human health, environmental, financial, and political costs (Hird, 2016). Incorporating waste into an epochal timescape does not simply highlight the temporal issues (re)created by and through waste (Erikson, 1994: Hird, 2016: Nixon, 2011: van Wyck, 2005) but also demands that we consider how waste flows can become entangled with planetary and nonhuman processes (Reno, 2015).

These issues are not constrained to the terrestrial but have become manifest within Outer Space also. O'Callaghan (2020) notes that Outer Space is already littered with a vast amount of 'space junk', estimating there to be >3,000 dead satellites, ~34,000 pieces of junk larger than 10cm, and 128 million pieces of junk larger than 1mm orbiting the Earth. Additionally, *Long March 5B*'s uncontrolled re-entry have brought the issue of space debris back to the fore once more (Murray and Sample, 2021). The size and scale of the 'space junk' issue will doubtlessly increase as interactions with Outer Space intensify and asteroid mining will have all manner of waste associated with its processes. However, as is typical throughout the mining sector, this issue has been overlooked at best and outright ignored at worst[59]. To begin addressing these issues, the silence surrounding waste *vis-à-vis* extractivism and Outer Space needs to be punctured. Presently, the principal means by and through which this silence may be addressed – or redressed – is via a sustained and critical engagement with the discourses of futurity and how these can be variously (mis)managed. With this in mind, I now

[59] Consequently, this research looks towards this issue in-depth throughout Chapter 6.

turn attention to futurity and the material and imaginative implications this bears for extractivism and Outer Space.

3.3 Capitalist Extraction, Disimagination, and Ethnofuturism

Having discussed the links between capital, extraction, and the 'frontier' and the way(s) this informs and structures the socio-politics of asteroid mining – in both its material and imaginary dimensions – I turn now to consider the role of imaginative practices. Specifically, I explore how discourses of futurity – whilst in themselves intangible – (re)produce or disrupt concepts of *the* future, bringing with them both imaginative and material implications. Thus, this section does not focus solely on the 'pure' imagination but discusses how this (re)shapes the socio-material, producing very real and tangible results over and through numerous media (policy, public and political discourse, etc.). This section explores this theme first through a broad discussion of 'future studies' and the attendant socio-politics. Subsequent sections then turn their attention to the process(es) of 'disimagination' and the transformative potential of Ethnofuturism[60] respectively; considering their implications for both the imaginative and the socio-material.

3.3.1 (Re)Making the Future and Socio-Material Becomings

Future studies has witnessed somewhat of a resurgence over the past decade or so and is an area that bears particular salience for the Social Studies of Outer Space given many of the topics covered in this area are inherently future-oriented. Given that asteroid mining is a proposed future activity rather than a present reality, future studies and the socio-material implications of future imaginaries are an important point of discussion when considering

[60] Both 'disimagination' and 'Ethnofuturism' are defined later, in their own particular subsections.

asteroid mining and its potential implications. Rather than being an exercise in clairvoyance, future studies seeks to look *at* rather than *into* the future (Brown et al., 2000); taking it as a dynamic site of social scientific inquiry (Tutton, 2017) that can shed light on a society or group's aspirations or fears. Indeed, I would propose that we can go further and suggest that debating futurity can – at its best – enable a politics of hope through its ability to contest and (re)shape socio-material realities that are still in the making or vie for new societal structures that are more equitable and just[61]. Recognising the dynamic potential in debating the future and taking it as a serious area of study necessitates a discussion on what the future *is* and how we conceive of it, which I will now consider.

The future, although intangible and temporally "ahead of us", makes itself "felt" in the present through various means of planning, prognostication, forecasting, expectation, and so on (Brown et al., 2000: de Laat, 2000: Frith, 1992: Geels and Smit, 2000: Lanier, 2013: Sanz-Menéndez and Cabello, 2000: Urry, 2016: van Lente, 2000). Indeed, the "future"[62] is often evoked in a broad sense, one that can mean a multitude of different things, to different people, at different times, in different places (Urry, 2016). The use of the term "the future" may produce for some the idea that it is an apolitical concept or 'thing': an empty space that is merely projected upon and existing in some pristine manner. However, the future is frequently evoked for political purposes, be this in politics itself, or businesses, boardrooms, academic institutions, and in the mundane, everyday (Frith, 1992: Jervis, 1991: Urry, 2016). In such instances, the future becomes imbued with a series of assumptions and narratives (Carr, 1981: Czarniawska and Hernes, 2005); the ability to realise these futures then being

[61] We may think here of numerous examples, the most notable at present being the global Climate Strikes and BLM protests.

[62] Placed in quotation marks here due to its complex nature and its being referred to in the singular whilst actually being comprised of the multiple.

translated and brought to bear in the present as actors seek to (re)shape the socio-material, creating (infra)structures that are considered necessary for these futures to become reality.

This relationship with the future – as a dynamic area that is contestable – is a relatively recent development and marks a notable shift from past conceptions of futurity. Within many premodern European societies, the future was considered the property of God, knowable, and – by extension – predictable; unable to be bent to the will of humans (Lowenthal, 1992: Urry, 2016). However, due to a combination of political, cultural, social, and religious shifts over the centuries (from Luther's divisive text, to various events throughout the period broadly referred to as 'the Enlightenment') the future became something that was hard, if not impossible, to ascertain or predict, shortening time horizons inciting people to increasingly give voice to what they wanted and usually wanting it within their lifetime (Lowenthal, 1992). Hence, contemporary understandings of, and relations to, the future have become increasingly complex; the term having come to encompass within it a wide variety of agendas, positions, beliefs, hopes, and fears, and is comprised of a heterogenous mix of outcomes and positions, no matter the topic at hand. Indeed, the future is heavily contested by numerous actors, be this generations possessing conflicting interests and concerns, cultural imaginaries of how various (im)material matters should be dealt with and governed[63], and those futures conceived of by the public, the private, and the in-between (Geels and Smit, 2000: Rose, 2000: Urry, 2016). It is perhaps best, then, to regard the future as "a contested object of social and material action" wherein actors must engage in a number of activities in order to have their future(s) heard, let alone realised, for:

[63] Or not governed, depending on the actor(s) involved.

> "if [various actors] are to secure successfully for themselves a specific kind of future then they must engage in a range of rhetorical, organizational and material activities through which the future might be able to be 'colonized'" (Brown et al., 2000; pp.3-4)

The use of the term 'colonise' here is rather apt as it neatly alludes to the establishment of ideological socio-political control by a particular group that subsequently shapes and informs material realities, often for their own gain(s) and at the expense of those 'others' outside of this group. This control is produced and maintained, in part, through the rhetorical, organisational, and material activities Brown et al. (ibid.) allude to. Another mechanism that contributes to the ideological control of the future and its attendant materialities is the process of disimagination; a sustained attempt at 'organised forgetting' that aims to foreclose alternative conceptions of the future (Didi-Huberman, 2008: Giroux, 2014). However, these attempts at foreclosure are rebutted and contested through alternative conceptions of the future, such as those created through Ethnofuturism. I will now consider each of these in turn.

3.3.2 Disimagination and Capitalist Realism

The preceding subsection discussed and outlined how 'the future' is a deeply contested and shifting entity; constituted by and through the melding of different temporalities[64] and a site of complex and dynamic debate. Consequently, a key part of futures is the pasts they draw upon and the narratives subsequently created around this. Furthermore, although frontiers[65] can be considered a material reality, the ideological undercurrents that drive engagements

[64] such as drawing upon the 'past' and 'present' to construct the contents of the 'future'.
[65] As space is often referred.

with these areas inevitably inform the socio-political-material relationships that take shape (Redclift, 2006). This is also true of Outer Space, which has had various ideologies projected upon it (Valentine, 2012) and been imbued with moral and philosophical deliberations (Arendt, 1958), resulting in a domain that is 'fully laden with cosmic dreaming, theological wonderings, and science fiction fabulations' (Kearnes and van Dooren, 2017; p.179). Taking these points in conjunction with one another, it is therefore important that we consider the role(s) of collective memory and the processes of disimagination *vis-à-vis* the (re)creation and perpetuation of Outer Space and asteroid mining futures and the socio-material relations these inform.

Collective memory is (re)created and maintained through the shared experiences and memories between various groups – be they of class, ethnicity, and so on (Halbwachs, 1992). However, collective memory is not something that is resigned to the past, passive and sedate. Instead – as previously noted – the past is drawn upon and mobilised in the (re)construction of social futures. Consequently, collective memory contributes to the formation of a dynamic past that is mobilised in the present to inform future imaginaries by and from various groups (Merck et al., 2016: Szpunar and Szpunar, 2016). Considering how interpretations and memories of the past shape various conceptions of the future, we can contemplate how collective memories – in their various guises and (re)telling – inform, in themselves, *collective imaginaries*. Recognising the role of collective memory in fashioning collective imaginaries requires a consideration of which group is shaping these narratives: what informs them, what they omit, and who is included and excluded through these processes. Rather than being a static category that passively has imaginaries projected upon it, the future is a dynamic arena wherein discourses of power can be mobilised and contested, reflecting present power geometries (Urry, 2016). The discourses adopted by NSE actors, for example, are used to

create future narratives wherein the physical enclosure of Outer Space is required to permit asteroid mining[66]. However, the mobilisation of collective imaginaries is not only used to justify the enclosure of physical space. They are simultaneously used to curtail and enclose imaginative spaces and the (counter)narratives therein through the process of disimagination.

The process of disimagination selectively edits the historical narrative, removing certain voices, modes of resistance, and alternative accounts, distorting the ability to imagine futures outside of the EuroAmerican neoliberal present (Didi-Huberman, 2008: Giroux, 2014). The process of disimagination has been used by Didi-Huberman (2008) to describe a series of acts and practices that attempt to remove a people or series of actions from the historical record – in this instance they consider the attempted destruction of any evidence of events that transpired in Auschwitz. Giroux (2014) adapts this terminology, using it to discuss critical pedagogy and its relation to contemporary politics. Giroux describes ". . . a politics of disimagination . . . in which stories, images, institutions, discourses, and other modes of representation are undermining our capacity to bear witness to a different and critical sense of remembering, agency, ethics, and collective resistance" (2014; pp.26-7). The latter of these two modes of engaging with disimagination has been primarily drawn upon within the context of this thesis. However, rather than engaging with a critical pedagogy lens, this work adopts the term and uses it to discuss a series of socio-cultural-political practices that are mobilised not only to (re)shape future imaginaries but that have material consequences attached to them[67].

[66] Discussed later throughout chapters 5, 6, and 7.

[67] For example, if we consider the popularization of asteroid mining futures – often discussed in the affirmative – this has led various actors to lobby and press for changes in legislation. This has been achieved to varying degrees in the UK, US, India, China, and Luxembourg. The effects are not limited to the bureaucratic realm of

Adopting a socio-cultural-political approach to the disimagination process allows for an engagement with – and incorporation of – various aspects of the decolonial/postcolonial agenda. It advances our ability to question *whose* future is being spoken of and the normative assumptions that reside therein. In relation to Outer Space and asteroid mining futures, it allows for a more critical engagement with the (neo)colonial discourses enmeshed in popular renditions of these futures and the means through which 'other' futures are side-lined or silenced. Indeed, it is through the processes of disimagination that the condition of capitalist realism is enabled – a state of affairs wherein it is easier to imagine the end of the world than the end of capitalism (Fisher, 2009[68]). Consequently, the 'popular' futures curated, maintained, and promoted by NSE actors are structured through a white-ethnocentric rendition of history. The resultant imaginaries and narratives implicitly and explicitly draw upon familiar tropes of white settler colonialism, such as enclosure, working land to produce 'value', and the displacing of indigenous/non-Western onto-epistemological frameworks, if not the people themselves[69] (Bhabha and Comaroff, 2002: Hesse, 2002: Loomba et al., 2005: Parry, 2002: Wilkes and Hird, 2019: Wood, 2017: Young, 2001).

In their discussion of capitalist realism, Fisher (2009) succinctly summarises the reciprocal relationship between the past – or canonical – and the new, where "[t]he new

law, but, through its permitting various activities, has led to flows of capital being (re)mobilized and (re)distributed, new launch sites being explored and lobbied for/against (see Bagnall, 2017: Gov.uk, 2018: Griffin, 2020: Hebditch, 2021: Kelly, 2020), and new manufacturing, administrative, and commercial infrastructures being set up or proposed.

[68] Whilst this quote has been attributed to several theorists over time – including Frederic Jameson and Slavoj Žižek to name but two – I reference Fisher here for his engagement with the wider concerns and processes of capitalist realism.

[69] However, although we can only discuss the continued exclusion of non-Western/indigenous onto-epistemological frameworks when discussing asteroids themselves, terrestrial implications surrounding land rights, ancestral lands, and sacred sites are not absent from these debates. Outer Space operations – both present and future – rely on large infrastructures and some of these projects have already caused disputes with indigenous peoples (such as the ongoing dispute over the Thirty Meter Telescope at Mauna Kea (Matson and Nunn, 2017: Smiles, 2020)).

defines itself in response to what is already established; at the same time, the established has to reconfigure itself in response to the new" (p.3). Although discussing the curtailing of the future that results in the state of capitalist realism, here we can see how the process of disimagination perpetuates and reinforces this state. If the new is defined through its response to what is already established, then the implications of the disimagination process' active destruction of alternative historical narratives become readily evident. Through destroying various historical narratives besides those which support the status quo, alternative modes of futurity are foreclosed and present socio-political structures – and their material implications – are perpetuated (Didi-Huberman, 2008: Fisher, 2009: Giroux, 2014).

However, to surrender to "the morose conviction that nothing new can ever happen" (Fisher, 2009; p.3) is to deny that which was noted at the outset of this section: that critically engaging with futurity can enable a politics of hope through its ability to contest and (re)shape socio-material realities whilst they are still in the making. This demands that we critically engage with and reflect upon our collective histories and – by extension – collective imaginaries, asking what normative assumptions they are based upon and what – or whom – they exclude. We must also search for those imaginaries that unsettle those (re)created through disimagination and capitalist realism. With this in mind, (neo)colonial futures and the disimagination process do not go unchallenged. Instead, there are innumerable alternative futures proposed from multiple peoples and groups. Indeed, Giroux (2014) posits that a number of sites remain wherefrom the disimagination process can be fought. These include – but are not limited to – "the new media, the alternative press, the uprisings and democratic participatory engagement being generated by youthful protesters all over the world" (p.202). Beyond these sites listed by Giroux, the dominant (neo)colonial futures and associated disimagination process are contested through the works of Ethnofuturists, their works and

subsequent futures drawing upon collective histories that lie explicitly 'outside' of the dominant EuroAmerican discourse. I turn now to consider and expand upon Ethnofuturism.

3.3.3 Ethnofuturism: (Re)Imagining the Futures

Despite the seeming dominance of a white-ethnocentric discourse of Outer Space futurity permeating the popular imaginary and the apparent effectiveness of the disimagination process *vis-à-vis* these futures, they are by no means unchallenged. The ethnocentric discourses surrounding Outer Space futurity coupled with the disimagination process operate to create the 'morose conviction' of a future foreclosed to any and all other scenarios. However, these discourses do not comprise a monolithic entity; instead, the seeming hegemony of this futurity is contested and disrupted via the provocations and (re)conceptualisations offered through Ethnofuturist writings and artwork[70].

The primacy of the ethnocentric discourses of Outer Space have been challenged over the past several decades through the works of Afrofuturism (Bould, 2007: Dery, 1993: Nelson, 2002)[71]. The work of Afrofuturism has done much to emphasise the ethnocentrism of Science Fiction (SF) and the space industry's discourses of the future (Bould, 2007). Dery defined Afrofuturism as "Speculative fiction that treats African-American themes and addresses African-American concerns in the context of twentieth-century technoculture – and, more generally, AfricanAmerican [sic] signification that appropriates images of technology and a prosthetically enhanced future . . ." (1993; p.736). This is an important site of disjuncture with a 'typical' futurism that is dominated by and through ethnocentric discourses. Indeed, as a

[70] Here I take 'artwork' to mean not just the production of images, but all of the 'arts' – writing, imagery, sculpture, music, and so on.

[71] For an overview of some social, political, artistic, and cultural engagements with Afrofuturism, see Bakare (2014), Bland (2015), Clark (2015), Minamore (2018), Roberts (2019), Sayej (2018), Taylor-Stone (2014), and Thrasher (2015).

historical phenomenon, futurism is associated with the artistic and social movement(s) of modernism in Italy circa 1918-1945 (Italian Futurism, 2014: Larkin, 2013: Marchicelli, 1996: Perloff, 2003: Rye, 1972)[72]. However, regarding futurism as a social phenomenon results in futurism becoming 'a belief in the future', whilst from an artistic, sociological, or anthropological perspective futurism comes to emphasise 'transformation rooted in the present world' (Quan, 2017; p.191). It is this latter perspective – that of the artistic, sociological, and anthropological – that this research primarily concerns itself with. Through adopting this position, Afrofuturism can be said to operate in myriad different ways and towards starkly different ends than EuroAmerican futurism. Indeed, Quan notes that "In contradistinction to Western futurism, Afrofuturism is explicitly antifascist insofar as it provides an imaginary domain for radical democratic politics and life-forms outside of white-supremacy, racial capitalism, and hetero-patriarchy." (2017; p.191). However, whilst Afrofuturism has succeeded in creating numerous inroads towards challenging and disrupting the ethnocentrism that permeates SF and the space industry, it focuses – by its very definition – upon black histories and cultures. Sites of engaging and critiquing the ethnocentric discourses of Outer Space futurity can be expanded through considering the multiplicity of *Ethnofuturisms* offered within contemporary futurism, enabled – in part – by Afrofuturism's history of breaking new socio-political-cultural ground. Shifting from Afrofuturism to Ethnofuturism allows for the expression of futures and cultural critiques from peoples and groups that do not fit within the black-white binary of Afrofuturism[73]. Some of the futurisms

[72] An important aspect of this period of futurism and its associated movement is its connection to Italian Fascism of the time (Marchicelli, 1996: Taylor, 1979: Taylor, 1961: Quan, 2017: Rye, 1972). Whilst there is work that discusses this link, there has yet to be any substantive work on the shift from this futurism to those of Afro- and Ethnofuturism.

[73] A particularly poignant point given the current focus on anti-Asian hate crimes in the U.S. following – or amidst – continuing debate and protest over anti-black racism.

included within the umbrella term 'Ethnofuturism' include (but are not limited to): Afrofuturism (Bould, 2007: Nelson, 2002: Yaszek, 2006), Aotearoa futurism (Wilson and Taipua, 2015), Cambrofuturism (ap Dyfrig, 2015: Jones, 2018), Gulf/Arab Futurism (Parikka, 2018) Indigenous Futurism (Guzmán, 2015), and Sinofuturism (de Seta, 2020: Tyfield, 2017)[74]. These various Ethnofuturisms continue the earlier work of Afrofuturism; using aesthetics and artistic formats to confound normalised notions of futurity but adopt different socio-political-cultural contexts (Parikka, 2018). These variegated futurisms are becoming increasingly salient for the aerospace sector as more nations – and, consequently, peoples – are becoming involved. Indeed, China, Iran, India, UAE, and Israel have all achieved various feats in recent years, disrupting the historical US-Russia-Europe dominance of the sector (Hickman, 2012: Hsu, 2010: Wall, 2015)

At its most basic level then, we may understand Ethnofuturism as an imaginative process that simultaneously engages the *Ethno-* (referring to the archaic, indigenous, or cultural histories of peoples) and *-futurism* (deemed the cosmopolitan, urban, and technological) (Hennoste, 2012: Kolcheva, 2015), creating a temporally hybrid space wherein cultural pasts and speculative futures collide and are blurred. Consequently, we may look upon – and engage with – Ethnofuturist worlds that draw upon non-EuroAmerican histories and cultural specificities as sites wherein – and whereby – the hegemony of the EuroAmerican onto-epistemological framework is agitated, contested, and refuted. It is important to note here, however, that the processes involved in Ethnofuturism should not be confused or conflated with that of disimagination as it operates to achieve different ends and means. Rather than seeking to silence another group's history or telling of events, Ethnofuturism

[74] We should note here that EuroAmerican Futurism constitutes an 'Ethnofuturism' itself that contains within it multiple, sometimes conflicting, futurisms.

draws upon these different histories to challenge and disrupt the seemingly *de facto* futures often presented through the EuroAmerican imaginary. Rather than a process that seeks the active removal or silencing of particular histories (as the disimagination process seeks to achieve (Didi-Huberman, 2008: Giroux, 2014)), Ethnofuturism is perhaps best thought of as an exercise of *re-remembering*, this being where its disruptive potential lies. Indeed, whilst writing on Afrofuturism, Quan notes that these processes should be regarded as a mode of time travel that allows for 'rememories':

> "Time travel, especially looking into the past for rememories of resistance in order to reimagine a just future, is thus radically different from a Western futurist fantasy in which Black cosmologies, Black epistemologies, and Black life world have been disappeared or merely acquired a functionary status as an appenditure [sic]." – (2017; pp.191-2)

Following from this, through creating artwork that draws upon histories and experiences other than those embedded within the EuroAmerican discourses of extraterrestrial imaginaries, Ethnofuturism operates as a powerful space wherein 'traditional' conceptions of extraterrestrial extractivism can be critiqued, frustrated, and reimagined (Quan, 2017). Through challenging the normative discourse of Outer Space futurity – where the familiar tropes of history and enclosure are meted out once more – Ethnofuturism offers us a means of thinking outside of this framework, asking and imagining what other futures may be possible and how these may be thought and done differently. Not only do these Ethnofuturisms operate 'as necessary antidotes to messianic billionairism and futurist racial

fantacies' (ibid; pp.192-3), they also provide fertile ground by and through which the disimagination process and its resultant imaginaries can be disrupted, challenged, and critiqued; providing space to free us from Fisher's 'morose conviction that nothing new can ever happen' (2009; p.3). Ethnofuturism, therefore, is a promising area by and through which we may attempt to decolonise the future – both conceptually and in practice – through challenging the disimagination process and the sense of 'capitalist realism' this (re)creates (Fisher, 2009: Giroux, 2014).

3.3.4 Ethnofuturism: Responding to the Materialities of Capitalism

Far from being consigned to the hypothetical and an immaterial future that bears little importance to the present, Ethnofuturism contains within it a transformative potentiality that can disrupt normative assumptions of how society can – or should – be structured and proposes new realities that can be realised with the right political and social will. Indeed, illustrations of Ethnofuturism's transformative potentiality abound. Two brief examples will suffice here. Firstly, consider Malorie Blackman's (2001) book *Noughts + Crosses* that was adapted into a BBC drama series. The story is based in an alternative UK where black people have access to the wealth and positions of power following the imagined legacy of African colonialism. Whilst fictitious, the inversion of racial divisions – placing black people into a position of power and having white people in positions of servitude – was enough to stir backlash and hysteria amongst various rightwing commentators. The second example is the recent toppling of the Edward Colston statue. Whilst its toppling has been embroiled in a debate around 'criminal damage', a wider reckoning with the UK's colonial history was demanded. However, simply calling for an honest conversation around this history and its continued legacy was enough to send various commentators and sections of the UK

population into an existential crisis where to even query the UK's historical narrative is now enough to be labelled 'unpatriotic' and a 'traitor' (see Jayanetti, 2020 for an overview of this discussion).

These two examples – the first an exercise in hypothetical futurity that holds a critical mirror to contemporary society, the second a call to simply include the diverse array of people's histories bound up in UK colonial histories – demonstrate the vast potential held by Ethnofuturism in resisting the neoliberal present and its attempts to perpetuate its own futurity through the disimagination process. Indeed, Ethnofuturism goes beyond the hypothetical, having material implications when enacted upon, producing through its discourses various modes of resistance that can be acted upon. One such example where the material implications of Outer Space futurity is being resisted and refuted is at the Mauna Kea Thirty Meter Telescope site, where Hawai'ian indigenous beliefs clash with the US's aim to use these cultural lands for their space projects (see Matson and Nunn, 2017 and Smiles, 2020 for further detail). This is but one example wherein socio-material relations are being contested due to different conceptions of human-material relations and how these can or should be managed and navigated. Consequently, Ethnofuturism can be said to not only hold a transformative potential through its ability to unsettle and challenge the *de facto* futures (re)created by and through the combined efforts of disimagination and capitalist realism but is also presently contesting and shifting socio-material relations; challenging societal structures and the normative assumptions that underpin these.

3.4 The Terracentric Turn

I turn now to consider the third 'decentering' this chapter explores: terracentrism. Whilst the first section focused upon decentering the imaginative and material through well-established

literatures on capitalism and extraction and the second focused on the influences of disimagination and (Ethno)futurism, this section is the most formative. It draws upon burgeoning fields within the Social Studies of Outer Space to disrupt the imaginative and material practices (re)produced through Earthbound onto-epistemologies that draw upon a singular planetarity, perpetuating with them a host of normative assumptions. This section broadly asks us to consider what happens when we begin to think outside – and beyond – the Earth?

3.4.1 Terracentrism: Earthbound Onto-Epistemologies

Although the preceding engagement with literatures on capitalism and the extractive industries have proven instructive in beginning our discussion on asteroid mining – from the (re)making of frontiers to the production and management of wastes – the extent of its applicability in Outer Space is necessarily limited. These limitations arise through the manifold shifting relations imposed by a complex matrix of (extra)planetary forces; creating vastly different conditions at different times and places. These shifting and complex conditions curtail the ability to simply adopt and apply existing logics of extractivism from Earth's (sub)surface to the extraterrestrial. Therefore, just as 'anthropocentrism' demands that we consider how the human is taken as the central point of concern throughout various problems or experiential modes of knowledge (De Castro, 1998: Hayward, 1997: McShane, 2007: Norton, 1984), here 'terracentrism' is proposed as a means by and through which we may begin to account for the way(s) the Earth – as a single planetary system or entity – is currently taken as the principal framing perspective in the Social Studies of Outer Space. Before moving on to consider some of the work that has begun to tentatively engage with this issue and the implications of multiplanetary thought, I will quickly address two issues here. Firstly, I will

briefly clarify a couple of points on terminology[75]. Following this, I will contextualise this thinking and consider whether this constitutes a 'turn' or if the issues of terracentrism have already been dealt with.

The first point here is an act of clarification. I am using the term 'terracentrism' to describe the primacy of onto-epistemological frameworks created in, and informed by, a singular planetary experience: that is, modes of thinking and existing that have been informed and (re)structured through Earthbound interactions. This is an important point of disjuncture from some instances of the term 'terracentrism' within geography, where it has been used to describe a focus upon the land as opposed to maritime locations (Mukherjee, 2014: Rediker, 2015). However, in their discussion of land-focused literatures and their relation to seafloor mining, Dalby (2007) describes this preoccupation with the land as 'terrestrocentrism'. Furthermore, as this work makes use of Science Fiction (SF) as a source of data, we should note that the term 'Terran' has been used to describe the inhabitants of Earth in SF since as early as 1946 (HDSF, 2020). Taking Dalby's (2007) terminology and working in conjunction with established references within SF, the use of the term 'terracentric' to refer to Earthbound onto-epistemological frameworks becomes common sense. Thus, to avoid confusion, this work uses Dalby's (2007) term 'terrestrocentrism' to refer to land-focused literatures and frameworks, and 'terracentrism' to refer to (planet) Earth-focused literatures and frameworks. 'Terracentrism', then, demands that we consider how the Earth – as a single planetary system or entity – is often invoked as the basis by and through which other planet(oid)s and their systems are (de)valued or ignored: multiplanetary specificities and

[75] Rather than being a simple exercise in pedantry, this is a necessary detour to avoid confusion with terminology found in some other areas of geography that may otherwise muddy the waters.

complexities that contribute to and constitute dynamic planetary systems being eschewed for frameworks that have developed through a singular planetarity.

Having dealt with the issue of terminology, I turn now to contextualising terracentrism and consider whether this constitutes a 'turn' or if it has already been realised. It could be suggested that terracentrism does not pose a conceptual turn due to the Copernican Revolution: the paradigmatic shift of the sixteenth century that rebutted the notion that Earth lay at the center of the solar system and replaced this idea with the heliocentric model. In this sense we have already witnessed a terracentric turn. However, the Copernican Revolution only occurred – indeed, was only relevant – in relation to our understandings of and relations to celestial mechanics: from conceptualising the solar system as being organised around the Earth to having the Sun lie at its center. Here, the 'terracentric turn' does not seek to describe the physical attributes or mechanics of planetary systems and their orbits (the work of Copernicus and the ordeals of Galilei having already (re)worked that dimension). Rather, the 'terracentric turn' is far more wide-reaching as it attempts to recognise and account for the conceptual predispositions our ontological and epistemological frameworks are rooted in through their having developed with and through a singular planetary system. This 'turn' demands that we attempt to critically appraise and account for normative modes of thought – both imaginary and practical – that stem from living with and upon Earth. It asks that we not only engage in a process of critical imagination – i.e. what can happen through moving off-world – but also demands that we critically engage with questions of materiality: how relations with mining and embodied practices shift through differing extraplanetary contexts. Thus, the 'terracentric turn' goes far beyond that of Copernican celestial mechanics, disrupting *a priori* conceptions of socio-material relations and challenging every normative assumption that underpins such relations as they manifest *on Earth*. It decenters the

imaginative and material realities of extraction through accounting for new planetary variables that have remained fairly static in a single planetary context (e.g. gravitational forces, atmospheric density, planetary hydrology, etc.). The 'terracentric turn', therefore, asks us to consider what onto-epistemological frameworks would develop on Mars, the Moon, or asteroids and whether we – as Terrans – would recognise them and their attendant logics? I will now consider literature that has tentatively begun to broach the terracentric turn and some of the implications of multiplanetary thought.

3.4.2 Beginning Terracentrism

As previously noted, there has yet to be any literature that directly addresses the issue(s) of the terracentric turn *vis-à-vis* the Social Studies of Outer Space. However, there are a few disparate publications that – taken collectively – have made tentative steps towards the topics encompassed by terracentrism. Perhaps the most notable discussions on the topic come from the fields of astrobiology and exoplanet studies. Here, the underlying assumptions on what constitutes life are the most readily available. Whilst 'outside' of the social sciences, looking towards these fields is both timely and salient for the Social Studies of Outer Space. The most pertinent work for the conversation at hand is Summer and Trefil's (2017) discussion on '*chauvinisms*'. In their work, Summer and Trefil discuss three chauvinisms that influence – even curtail – our search for extraterrestrial life. These are : 1) Carbon chauvinism – the belief that life must be carbon-based; 2) Surface chauvinism – the belief that life will be present on the surface of a planet; and 3) Stellar chauvinism – the belief that life must inhabit a planet around a star like 'ours'. Whilst Summer and Trefil do not use the term, these 'chauvinisms' all arise from terracentric onto-epistemologies; the belief that things must adhere to the rules as they present on Earth. However, as Summer and Trefil discuss, there are numerous

discoveries that have led the primacy of the terracentric model to be questioned (e.g. discovering liquid water on other worlds). Moreover, there is a growing recognition that planet(oid)s are not closed systems but are dynamic entities that are acted upon – and interact with – 'external' forces such as asteroids, comets, and gravitational masses (Clark, 2005: Davis, 1996). Taken collectively, these literatures have begun to disrupt the notion that celestial bodies – including the Earth – operate in closed systems, being open to multiple (inter)planetary forces that make them infinitely complex.

Beyond the search for extraterrestrial life and planetary systems, the influence of these forces on human-space relations has been touched upon (or tangentially indicated) by a handful of papers that broadly fall within the Social Studies of Outer Space. Some literature has started to look at how Outer Space is 'humanised' through increasing interactions between society and Outer Space. These literatures have examined how Outer Space is being (re)created as a site of adventure and novelty, engaged with in a 'narcissistic' manner to (re)produce a site of intrigue (Dickens and Ormrod, 2007: 2009: Ormrod and Dickens, 2019) or how sociable life influences the planetary (Clark, 2011: Clark and Gunaratnam, 2017: Clark and Szerszynski, 2020: Johnson et al., 2014). However, these literatures examine how human society is (re)creating Outer Space. To begin to challenge a terracentric disposition requires the inverse to be explored: to consider how Outer Space and the shifting contexts therein (re)shape – even confound – socio-material realities that are taken for granted in an Earthbound setting. Presently, the only paper to begin considering this question from a social science perspective is Parkhurst and Jeevendrampillai's (2020) work exploring emotion and embodiment in microgravity environments. Here, they explore how microgravity can impact on social relations through its distortion of normative bodily alignments and gestures, physics influencing the anthropology of the 'body in movement' (ibid, p.6). However, whilst Parkhurst

and Jeevendrampillai's work has begun a welcome conversation on the influence(s) of Outer Space on socio-material realities and relations, it only considers this in relation to the embodied experiences of being in Outer Space. The 'terracentric turn' goes beyond this, calling into question every aspect of our onto-epistemological frameworks – the embodied, material, and the imaginative.

Thus, concerted conversations within the Social Studies of Outer Space are beginning through disparate literatures that all allude to terracentrism without directly engaging with it. By taking these literatures as a collective and bringing them into conversation with one another, it could be said that we are finally 'beginning terracentrism' within the Social Studies of Outer Space. I will now consider the implications this poses for multiplanetary thought.

3.4.3 Beyond Terracentrism: Multiplanetary Thought and (Extra)Planetarity

Recognising that the 'terracentric turn' demands that we question the basic assumptions that Earthbound onto-epistemological frameworks are predicated upon and that this turn has tentatively begun through the aforementioned literatures, I will briefly consider some of the implications this poses for the Social Studies of Outer Space and asteroid mining more specifically. Rather than asking how Outer Space is (re)created through human-space interactions, critically engaging with and recognising terracentrism demands a consideration of how Outer Space (re)shapes various socio-material realities through a complex and shifting matrix of (extra)planetary forces. This process decenters both the material and imaginary dimensions of extraterrestrial extractivism that are otherwise taken for granted. Instead of adopting and accepting *a priori* conceptions of how asteroid mining – and Outer Space futurity more generally – may look and operate, moving beyond terracentrism demands that we question the very suppositions upon which these normative discussions are predicated.

Going 'beyond terracentrism' requires us to move away from foregrounding discussions in social, material, or socio-material terms. Instead, a recognition of our terracentrism demands a leap in our intuition: to begin our discussions in reference to the multiplanetary context within which our work is situated and the (extra)planetary forces these sites may entail. This shift in framing is paramount if the Social Studies of Outer Space is to move beyond terracentrism and the onto-epistemological frameworks this subtends. This shift would demand that work on Outer Space account for the (extra)planetary forces and contexts wherein, and whereby, the material and social are informed, influenced, and ultimately defined. These (extra)planetary forces include, but are not limited to, gravitational force, mass, atmospheric pressure and density, surface temperatures, whether or not there is a magnetosphere, distance from the sun, axial tilt, and the planet or planetoid's geology. Such (extra)planetary forces must be brought to the fore when discussing materials and the socio-politics they are bound up in. These forces are important in the terrestrial context but become of yet greater import when we go beyond the terrestrial context; an alteration within any of these forces bearing the potential to reshape or even confound our ability to grapple with the socio-material realities of each site of extraction and exploration. Indeed, a critical engagement with terracentrism not only demands that we enact a mode of critical imagination – to ask what can happen through moving off-world and through shifting contexts – but also asks that we critically engage with questions of materiality: what new modes of working or being come about from moving in and through various, shifting contexts? Consequently, the terracentric turn poses the most radical form of decentering of the three sections discussed, posing the potential to disrupt the Social Studies of Outer Space as it presently exists.

Chapter 4: Methodology

4.1 Introduction

This chapter outlines the methodology adopted for this project. It begins by considering questions of my positionality and reflexivity: experiences that have shaped my interests in extractivism, capitalism, Ethnofuturism, and futurity. It then moves on to consider some of the challenges posed by this research: how futures can be researched and how researching something that is both spatially and temporally distant can be achieved. After addressing this, a brief discussion on the challenges of trying to think beyond terracentrism and communicating this process is had. The remainder of the chapter concerns itself with how data relating to the three 'decenterings' of this work was generated to develop subsequent conversations. Specifically, these sections relate back to the discussion on a speculative methodology: how a matrix of 'concrete data' opens up sites of opportunity for "deep empiricism", speaking towards a world that is always in the making and allowing these 'decenterings' to come to the fore where they may otherwise be consigned to silence. Furthermore, this process responded directly to the issue of how to collect information on asteroid mining futures that take for granted capitalism, Eurocentrism, and terracentrism.

4.2 Positionality and Reflexivity

Before delving into a conversation about the challenges posed by this research, how they were overcome or circumvented, and the subsequent methods employed to generate data, I turn first to consider matters of positionality and reflexivity. Prior to elaborating on my positionality and the way(s) this has informed my research interests, I turn first to briefly consider the matter of reflection and reflexivity.

Whilst Patai's (1994) assertion that we cannot escape the consequences of our positions through endless discussion holds some appeal, the answer cannot be to simply remain silent on the matter (Pillow, 2003). Indeed, it is important that I critically reflect – and subsequently reflex – on my positionalities in order to position myself ethically and to acknowledge the power dynamics within my research. Reflection and reflexivity are two distinct yet complimentary processes. Here, I take *reflection* to be a critical appraisal of oneself and the various aspects of one's identity that are pertinent to the research at hand. *Reflexivity*, however, demands that we not simply appraise ourselves and remain static – as *reflection* implies – but that we act upon what we find. This helps address issues of power within the research process and allows research to be scrutinised for ethical 'rigour'. Consequently, *reflection* is the process whereby these various attributes are first encountered and explored, and *reflexivity* is how these findings are reacted to and addressed. Throughout this research process, I have yet to find a suitable point at which to stop this process. Instead, I would argue that this process should never cease: research always moving through a perpetual cycle of reflection and resultant reflexivity, questioning one's position, the choices made, and the role adopted within the research process (Berger, 2015: Bott, 2010: Finlay, 2002: Hay, 2003: Mason, 1996: Pillow, 2003). This was – and remains – an uncomfortable process: this perpetual cycle meaning there has never been any certainty in the research process and has brought with it many questions and self-doubts – compounded, in part, by aspects of my positionality (see below). Given this, I have engaged in acts of self-care at times to think through and reconcile some of this discomfort (see Jones and Whittle, 2021 for example). Ultimately, the didactic process of reflection and reflexivity, through their ability to strengthen the research and account for power asymmetries, has led me to an oxymoronic position: that I have had to learn to become comfortable with being uncomfortable.

As alluded to above, the complimentary processes of reflection and reflexivity are pertinent when trying to uncover and critically account for the power dynamics involved throughout the research process. Power is an integral part of the research process, being present before, during, and after the research has taken place. Indeed, the power dynamics involved in research pose significant implications for a project's ethics (e.g. am I abusing my power?) and for the information that may be divulged during the course of fieldwork (however this manifests) (Baxter and Eyles, 1997: Dunn, 2005: Eyles, 1988: Kobayashi, 2001: Longhurst, 2003: Silverman, 1985: 2003: 2011: 2013: Valentine, 1997: Winchester, 2005). Whilst this was pertinent throughout the research process, a key assumption within much of the attendant literature is that the researcher occupies a position of power that is greater than, or at least equal to, the research 'subjects' (Nader (1972) refers to this as studying 'down' or 'across') (Bilmes, 1992: Dowling, 2005: Kobayashi, 2001: Skelton, 2001: Smith, 1999). A question that is seldom considered and became of interest/concern during this research is what happens when this power relationship is inverted? When the researcher is the one out of place and lacking the social and cultural capital to 'blend in', be 'in control', and could be removed from the site of study (whether this threat was real or imagined)? These questions will be considered *vis-à-vis* my positionality and this research in what follows. It begins by considering how being Welsh and growing up in a (post)extractive colony has influenced my research interests. The section then moves on to give attention to what a working-class identity meant for the research process: a research project that has engaged with 'elites', culminating in what Nader (1972) referred to as 'studying up'. This latter section specifically engages with the previous provocation: what happens when research power relations are inverted and what does this mean for the research process? The section

concludes with how these positionalities have come together to inform my research interests in Outer Space futurity.

4.2.1 *Cymro, Creigau, ac Annibyniaeth*[76]

Of the positionalities noted above, I turn first to consider my Welsh identity. Having grown up in Wales at the time I did and the (ongoing) debates I encountered have influenced various aspects of my research interests. Specifically, this has shaped some of my interests in (post)colonialism, extractivism and waste, and Ethnofuturism. To give a full account of the ways my Welsh identity has informed this research would exceed the confines of a thesis and would produce instead an autobiography. Consequently, I will necessarily limit aspects of this conversation for the sake of brevity.

The village I grew up in sits on the western flank of *Moel Hiraddug*, a mountain on the Clwydian range (*Bryniau Clwyd*[77]) and overlooks the Vale of Clwyd (*Dyffryn Clwyd*). Part of this vista is Rhuddlan castle (*Castell Rhuddlan*) (Figure 4.1). This fortress is not the only reminder of imperial rule, Rhuddlan having hosted Edward *I*'s parliament for the signing of the *Satute of Rhuddlan* (Figure 4.2). These are but two reminders of a tumultuous history that (re)shaped the area I grew up in in various ways. However, what was curious when I was younger is that this history was never taught in school; despite it being ~4 miles away. The historical legacy that this represents is bound up with the politicisation of the Welsh language (*Cymraeg*) and why Welsh place names have changed over the last century[78]. There have been numerous calls during my lifetime demanding that Welsh history be taught (BBC News, 2019: Cambrian

[76] 'Welshman, Rocks, and Independence'
[77] When referring to places, I will be including the Welsh name as there is a long history of Welsh place names being erased in favour of English alternatives (see Gwenllian, 2020: Lloyd, 2020).
[78] See https://decolonialatlas.wordpress.com/2015/03/09/wales-in-welsh/ for a map with contrasting Welsh and English place names in Wales.

News, 2017: Evans, 2013: Gillibrand, 2019: Hughes, 2019: Lewis, 2019: Madoc-Jones et al., 2013: Morris, 2019: Segrott, 2001) and contemporary 'debates' on the Welsh language are consequences of these silenced histories (Brooks, 2017: Cosslett, 2017: 2018a: 2018b: 2019: Dąbrowska, 2017: Morris, 2019: Price, 2018). This attempted silencing of history and at erasing a language resulted in an early interest in issues of power and cultural representation, these having developed over time, bringing me into contact with ideas of disimagination and how this process is mobilised and brought to bear on certain peoples and histories.

Figure 4.1: Rhuddlan castle from various aspects (personal photographs)

Figure 4.2: A commemorative plaque noting that the Statute of Rhuddlan was signed here (Personal photo).

Whilst growing up on the flank of *Moel Hiraddug* provided a thought-provoking vista *vis-à-vis* history, language, and – eventually – disimagination, by far the most pressing and

pertinent aspect was the sheer volume[79] of extractive legacies that surrounded me. My village and the surrounding area all bear the marks of extractivism in various guises: from the mines of *Talargoch* in the 13th century, to the aducts that run parallel to them, the Clive engine house, the quarrying of limestone from *Moel Hiraddug* (Figure 4.3) and its associated lime kilns (Figure 4.4). Indeed, whilst growing up in and exploring North Wales (*Gogledd Cymru*) mines and quarries were frequent sites: land having been scarred in pursuit of materials such as slate, gold, copper, lead, and limestone, to name a few. The legacy of extractivism extended beyond the scarification of the landscape. Most notably, infrastructures such as the Clive engine house and the lime kilns remain as reminders of this extractive history. The Dyserth-Prestatyn walkway is the old railway that once took limestone from the quarry to other parts of the country; the doctor's surgery was once the quarry offices; and some machinery still remains in the quarry to this day.

[79] Pun intended.

Figure 4.3: The disused quarry at Moel Hiraddug (personal photographs).

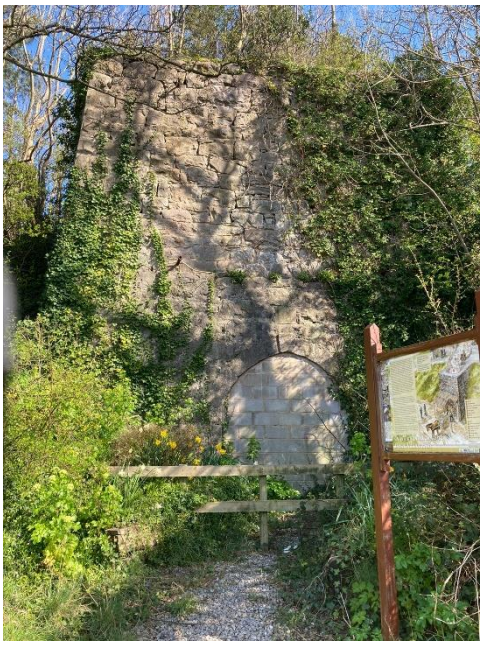

Figure 4.4: A lime kiln near the quarry. The more 'modern' ones were removed (personal photograph).

Moreover, whilst much of the interest in extractive industries such as mining and quarrying lies with the removal of materials, growing up in a post-extractive area has inevitably led me to consider the issues posed by the 'aftermath' of extraction that is frequently elided: waste. The material 'legacy' or 'aftermath' can be found throughout North Wales – indeed, I often played in these areas when I was growing up. These sites have given

me an appreciation for issues posed by legacies of extraction. Indeed, the dangers posed by waste are embedded in Welsh national history through the tragedy of Aberfan, having arguably defined a generation (McLean and Johnes, 2000: Miller, 1974). Waste is not consigned to Wales' history but is something that continuously arises, there having been numerous issues with mining waste legacies (Fairclough, 2021: Lewis, 2021). Waste and its attendant temporalities has also been a flashpoint in recent Welsh politics with the proposed dumping of nuclear waste off the coast of South Wales (*De Cymru*) and has even become an issue in my home county of Denbighshire (*Sir Dinbych*) where the government offered £1 million just to hear plans to dump nuclear waste there (Brennan, 2019).

Whilst growing up in the village I did shaped thoughts that would develop into interests in disimagination and the processes of extraction and waste, just as important is the *time* that I grew up in Wales. This period has seen the devolution process and a growing *annibyniaeth* movement. These aspects of the Welsh socio-political landscape have brought with them questions of futurity and national future-building; culminating in what ap Dyfrig (2015) has referred to as 'Cambrofuturism' (*Cymruddyfodoliaeth*). Whilst my engagements with 'Cambrofuturism' as a child came in the form of *Superted* and *Cadwgan y Llygoden o'r Lleuad*, questions of futurity – and, specifically, Welsh futurity – became ever-more commonplace. Indeed, not only was I introduced to modes of Ethnofuturism through the *annibyniaeth* movement and Welsh cultural artifacts and media but – crucially for this work – Ethnofuturisms were also present in the extractive histories embossed upon and beneath the surrounding landscapes. The historical legacies of extraction are arguably the physical remnants of certain modes of Ethnofuturism: of how certain materials could or should be related to, engaged with, and extracted. These histories could be (re)read through multiple Ethnofuturist lenses: as an Imperial/colonial futurism imposed upon the 'internal colony'

(Hechter, 1975), a Welsh futurism with the links between mining, language, and resistance (see Manning, 2002), or as part of the libertarian futurism that was subsequently exported throughout the world (Brooks, 2017). Moreover, engaging with my region's history in such a way also drew me into thoughts on the dehumanisation of miners generally (see Clark and Szerszynski, 2020), made all the more poignant through the cultural and linguistic 'othering' imposed upon Welsh miners (Hechter, 1975), though the language itself was mobilised as a mode of resistance in the face of this othering also (Manning, 2002). Through these discussions, I had already become familiar with some of the key dimensions of Ethnofuturism and how this can respond – in part – to the disimagination process, though I was unaware of this at the time.

Consequently, growing up where I did – and particularly at the *time* I did – has informed and shaped some of the topics that I find of interest in this research. The history and future – and how these interact – have frequently been a part of my lived experience on the 'Celtic fringe' (Hechter, 1975). It has shaped my interests in attempts to silence history, efforts to reinvigorate it, and how this can be – and is – brought into conversation with ideas of futurity. Crucially, it has led me to think about extraction at different scales at various points: from myself playing in quarries and mines, to my local area's legacy infrastructures, and to the (inter)national when thinking about where all of this material ended up. These aspects have culminated in a set of interests and questions that have been pertinent throughout this research, driving particular lines of inquiry at various points. Through critically engaging with the provocations provided through a Welsh positionality – the imposed Imperial versus Welsh Ethnofuturisms, relations between capital and extraction, and issues of waste – there are numerous parallels and points of disjuncture with asteroid mining that seemed both problematic and in need of critical appraisal. Noting this, studying asteroid

mining promised a fruitful area of study that would allow me to pursue the interests I have developed whilst bearing the potential to interject something on the matter before it has happened, hopefully avoiding some of the issues of 'aftermath' that home taught me about.

Crucially for this topic of research are the ways in which these various aspects of my positionality intersect with areas of interest within this thesis, including matters that lie at the heart of Ethnofuturism and postcolonialism. Although these two areas often centre themselves around matters of race, there are several areas of congruence between my own positionality and the issues discussed within Ethnofuturism generally and my interviews more specifically. Whilst a key site of disjuncture between myself and the Ethnofuturists worked with throughout the course of this research is that of race – positioned as I am as a White male – there remained several key areas within which constructive conversation on (post)colonialism and alternative futurity occurred through my Welsh identity. Indeed, upon finding out that I was Welsh, several interviewees noted that I would 'get what they were talking about' as we began discussing matters of independence, extractive histories, alternative political imaginaries, and – perhaps the most common theme raised – the politics of identity, language, and belonging. These areas of common interest – afforded to me by my Welsh positionality – enabled several discussions to readily occur where they otherwise may have been stifled or missed, my ability to 'get it' enabling some conversations to readily flow and connections with interviewees to be made. Consequently, whilst matters of race remained a clear site of disjuncture between myself and my Ethnofuturist interviewees, this positionality enabled a means of socio-political bonding that opened conversations up to new avenues of discussions where silences may otherwise have remained.

4.2.2 Of Other Worlds: An Alien in the Field

Having considered some of the influences that being Welsh at this time has played in shaping this research, I turn now to consider the role(s) of class in my research. There has been a recent (re)turn to considerations of class within academic circles. Although this is a welcome development, the principle means of discussion are frequently unrelatable and far too quantitative in their approach and framing[80]. Whilst quantitative approaches can be useful and assist our discussion and modes of analysis, to simply reduce class to such abstractions as Gini coefficients and metrics of household income is to render many aspects of class silent, and those aspects voiced through these means incomprehensible to many people they are discussing. Consequently, this resurgence of class within the social sciences must be accompanied by an engagement with the diverse qualitative elements and experiences class and its manifestations entail. To discuss class solely in terms of quantitative metrics is not merely an abstraction but an aberration also, a melding of aspects of class without the sinew to hold it all together or to provide any substance. Surely the purpose of discussing class – from popular discussions in the 19th century through to present – is to attempt to assess and improve the manner and means by and through which people live? If this is the case, then any analysis lacking a thorough engagement with qualitative research should be considered incomplete at best, devoid of true meaning at worst. It is this lack of engagement with the qualitative aspects of class that this section seeks to address through considering what it means to be a working class-academic and the implications this has had for the research process[81] and my experience of the academy more generally[82].

[80] This is a particular issue when researchers conflate class and Socio-Economic Status (SES), the difference between which is expertly defined by Crew (2020).
[81] Specifically 'studying up'.
[82] For example, using the phrase 'the academy' was alien to me before becoming involved in it.

Whilst a working-class identity and its attendant positionality may seem ‘trivial’ to some, this has not been my experience and has been noted by other researchers (Allen, 2017: Anonymous, 2017: Binns, 2019: Dews and Law, 1995). There is a growing body of work exploring the experience of working-class academics within the academe (see, for example, Attfield, 2016: Case, 2017: Cleland, 2017: Currie-Patterson and Watson, 2017: Hurst et al., 2017: Lee and Maynard, 2017: Vossen, 2017: Warnock, 2016) but there remains to be any work considering the perspectives and experiences of working-class academics conducting research in 'classed' spaces, questions around how to navigate such worlds when one may lack the social or cultural capital to 'pass', the embodied experience of discomfort within these spaces, and the lack of 'control' one may have in 'the field' despite the assumed power relations between researcher and researched. Drawing upon Katz's (1994) work on constructing 'the field', I shall proceed to consider the implications class has within the field, the power(lessness) (re)created through these relations, and the implications this posed for the research.

4.2.2.1 Being Working Class and ‘Studying Up’

Whilst the preceding section sought to explore how my Welsh identity has influenced and shaped aspects of my positionality, I turn now to consider the implications my class identity has brought to the research process: especially a topic that has engaged with various elements of ‘studying up’ (Nader, 1972). Having been acutely aware of my working-class background even as a child is partly what led me to take an interest in various topics pertaining to social justice, power, and how this is manifested through capitalism[83]. These interests never ceased and I was fortunate growing up that I had a family – parents,

[83] I will freely admit that it was never articulated so clearly when I was younger!

grandparents, aunts and uncles – that encouraged me to pursue education and explore the things I was interested in. Although this research looks to Outer Space and its future(s), these interests have shaped the research aims and underlying theoretical concepts that I have engaged with.

A working-class identity is not something that simply dissipates through obtaining one or more degrees (Connolly, 2017: O'Neill, 2017: Purcell, 2017: Reynolds, 2020) but is something that remains a part of my identity. Class has informed – in part – my habitus. This class-based habitus has been informed over several decades and can neither be 'escaped' nor 'erased' (nor should it be). Instead, rather than my working-class identity being removed or 'disguised'[84], at most it is something that I will have to navigate throughout academia, 'straddling' the class divide within which I now find myself (Attfield, 2016: Lubrano, 2004: Warnock, 2016). I specifically use Bourdieu's term 'habitus' as it refers to both the embodied experience (the *hexis*) and the mentality created through intersectional experiential knowledges and the various capitals this entails (Bourdieu, 1992: Byrne, 2015). Considering the habitus I have developed through growing up (and, to varying degrees, still being) working-class, the research process involved throughout this thesis has necessarily led to 'studying up' in numerous ways. This was perhaps most pertinent when engaging with people in NSE conferences, a distinctly different set of norms and habitus accompanying the people and setting. Mindful of this, a particular reflexive question has repeatedly troubled me throughout the research process, namely: am I the right person to conduct this research? This self-questioning is hardly surprising given the general experience of being a working-class

[84] Some working class academics opting to 'pass' than 'stand out' (Binns, 2019: 2020: Britain Has Class, 2017a: 2017b: Burnett, 2017: Crew, 2020: Dews and Law, 1995: King, 2017: O'Neill, 2017: Smolarek, 2019: Warnock, 2016).

academic[85]: this inevitably leading to questions of whether I should even be in academia more broadly, let alone interviewing Executives of multi-million dollar companies and associated consultants. Having gone through a perpetual cycle of interrogating myself on this issue, I believe there are two answers to my suitability *vis-à-vis* this research area and interviewing 'elites'[86], or 'studying up' (Nader, 1972)[87].

The first answer to this question is that I am *not* suited to engaging with 'elites'. Perhaps the habitus that I have developed through growing up in a working-class community has curtailed my ability to successfully engage in the interviewing of 'elites'. Being in a room full of NSE 'elites' was a deeply uncomfortable experience and many of the norms within the events attended were alien to me. The embodied discomfort of simply being there may have precluded certain information being gained that another researcher with a different class-related habitus may have had access to (Hoskins and Stoltz, 2005: Wolgemuth and Donohue, 2006). Ultimately, this discomfort and mismatching of habitus may have resulted in 'mishearings' (Bilmes, 1992) and implicitly or explicitly influenced how and whether certain questions were asked and subsequent discussions had (Hoskins and Stoltz, 2005: Wolgemuth and Donohue, 2006). The influence of my working-class identity and associated habitus may have affected these aspects of the data collection period, 'studying up' meaning alien forms of gatekeeping and interaction were likely encountered (Gilbert and Sklair, 2018: Miller and Glassner, 1997: Nader, 1972) and that I may have been more susceptible to what Mason-Bish (2019) refers to as the 'elite delusion'. Mason-Bish defines the 'elite delusion' as "the

[85] Issues of 'imposter syndrome' and 'belonging' within academia being frequently discussed (Allen, 2017: Anonymous, 2019: Binns, 2019: 2020: Britain Has Class, 2017a: 2017b: Byrne, 2015: Dews and Law, 1995: Olah, 2019: Reynolds, 2020: Smolarek, 2019)

[86] I place 'elites' in quotation marks here as this is a contested term within 'elite studies' and is given further consideration later in the chapter..

[87] I discuss this in the present tense as although the research has now concluded, this is something that I am still grappling with.

perception that elites are difficult to access and the researcher must be flexible and indeed grateful for any of their valuable time that is available" (2019; p.264, emphasis added). It may be that those with different class-related habitus could encounter the 'elite delusion' also, but what does a working-class identity bring to this dynamic and would this delusion and the associated discomfort be felt more keenly? The answer to this would be merely speculative and I can only speak of my own experience. I believe I was afflicted by the 'elite delusion' and that – although common – part of this may be attributed to the discomfort brought about by the stark mismatching of class habitus encountered through this research process.

Moreover, perhaps some aspects of the interview processes would have benefitted from my being more 'assertive', class identities shaping how various emotions are experienced, embodied, and acted upon. As Mughal notes of the working-class experience: ". . . much of class culture is about confidence. Confidence that might come easier to the middle and higher classes, while the working classes are constantly riddled with self-doubt and imposter syndrome" (2017; p.71). Indeed, the idea of 'assertiveness' is inherent within the academic environ and can have stark consequences throughout the PhD experience and the research process more broadly (see Anonymous academic, 2017). However, this is an action that can be read differently and divergently depending upon one's habitus and positionality. Rather than being a normative action, 'assertiveness' is experienced and interpreted in various ways – it is an action that has different readings and meanings ascribed to it based on a range of intersectional identities and positionings (Abu-Lughod and Lutz, 1990: Lutz, 1990: Reger, 2001: Rosenberg, 1990: White, 1990), amongst which is class. Far from having a *de facto* meaning, 'assertiveness' – in other guises and settings – may be interpreted as a host of other actions (such as aggression, entitlement, and ignorance, to name a few). Ultimately, I opted for a 'gentler' approach to my interviewing method, allowing interviewees to become

comfortable in conversing with me and forgetting about the Dictaphone between us. This approach felt the most comfortable and fitted my interviewing style more, allowing me to focus on the conversation at hand rather than being distracted with maintaining a performance for the sake of some amorphous, ill-defined 'assertiveness' that would have added to the discomfort this strange setting had already created.

However, a second way of answering the question of my suitability to interview elites would be that I am. Indeed, with a working-class identity and habitus – and all that it entails – it could be argued that I am better suited to interviewing elites and analysing any resultant data than colleagues that have seemingly more commensurate positionalities with regards to elites. Far from construing a working-class positionality as a flaw, it is more fitting to consider it a boon. Various commentators have noted that, despite claims within universities, academia still remains an elitist institution with various data existing to affirm this assertion (Allen, 2017: Anonymous, 2017: Binns, 2019: Burnett, 2017: Busby, 2019a: 2019b: Byrne, 2015: Crew, 2020: Dews and Law, 1995: O'Neill, 2017: Purcell, 2017: Smolarek, 2019). Whist academia remains an elitist institution, there are a series of normative assumptions that permeate the academic landscape: assumptions that are structured by white, male, middle-class, heteronormative dispositions (Reger, 2001). With this observation in mind, I would argue that a working-class habitus and positionality is more well-suited to the study of 'elites'. I posit this as a working-class positionality resides 'outside' of the dominant – or normative – positionality of academia, meaning new questions and subsequent insights could be generated. It has been noted that more diverse workforces – amongst which are classed positionalities – bring with them the advantage of a greater range of views, allowing for more inclusive readings of various situations and research areas (Attfield, 2016: Burnett, 2017: Carson, 2017: Jones, 2011: Major and Machin, 2018: Sarpong, 2017). Consequently, my

working-class positionality provided me with a different view of how things are and caused me to question what some (or many) of my peers and colleagues have taken for granted (Jones and Whittle, 2021). This questioning through encountering numerous rules and assumptions that have previously been alien to me is where my suitability – the positional 'boon' – is located. Being thrust into environments and encounters wherein all aspects were unknown to me resulted in my questioning and noting everything and anything: including that which may appear mundane to researchers with different class positionalities. Far less can be taken for granted or assumed as a norm when nearly everything experienced is new or so far removed from my default habitus to be considered the *de facto* way things are[88]. It provided me with a different lens through which to question normative statements that those with a different class habitus may have missed or left unquestioned. Through the questioning produced by and through the mismatching of my class positionality and the 'elites' studied, the data generated during this work and its subsequent analysis was likely enriched. I posit this as nothing could be taken for granted, most – if not all – of my interactions were 'unstable', being revisited and reanalysed to make better sense of them, producing new readings and understandings each time, yet always remaining unsettled. This leaves me with a question for this research process: would I have revisited my work so much if I had not felt so uncomfortable and out-of-place given that some of this reworking was motivated through doubting myself and seeking reassurance through this (re)work?

[88] For example, one colleague joked that they had not encountered a world of meals with 'more than one knife and fork' before attending university.

4.2.3 An Interest in Outer Space Futurity

These positionalities have come together to inform and shape my interests in Outer Space futurity. Growing up in Wales – particularly at the time I did – brought me into contact with a medley of issues that have informed this research. A history of extraction and imperialism was all around me, debates on language and the histories this invokes are still ongoing, and the devolution process and its questions of Wales' future began when I was young. These questions of Wales' future have only become more pertinent over time with the growing *annibyniaeth* movement over recent years. Amongst all of this were my budding interests in social justice, power, and how this related to capitalism: things I tentatively considered whilst playing in and around abandoned quarries and mines without the language or means through which to express or thoroughly engage with them. Whilst these varying interests may at first appear amorphous and disconnected, they are all of relevance to this research and my interest in asteroid mining. The links with capitalism and extraction are obvious: the latter informing aspects of my interviews and the questions posed, focusing not just on the processes that would make extraction possible but also drawing me to explore issues of mining waste – something that is hard to forget in a former mining village. The interests in social justice and power have linked with matters of Welsh language rights and class, asking who speaks for various people, who makes decisions, and how are these enforced? Finally, debates on the future of Wales (what ap Dyfrig (2015) refers to as 'Cambrofuturism' (*Cymruddyfodoliaeth*)) have driven an interest in Ethnofuturism and how its (re)articulations of the future can decenter and disrupt *de facto* futures, something this research sought to do.

4.3 Researching Futures

The research topic and its attendant questions are inherently interested in the future and, consequently, the research process oriented itself to the future accordingly. This posed its

own series of challenges for the research process beyond those we typically encounter[89]. Firstly, there is the issue of how to research something that does not presently exist – an inescapable issue of future studies. Secondly, the challenges are not limited to attempting to look beyond temporal horizons but are also rooted in the restraints of spatial horizons also. Specifically, how can we research something that is completely inaccessible, where we cannot experience the site of research interest and experience the materialities that – in part – co-constitute and inform debates and conceptions of asteroid mining? To overcome these challenges, a speculative methodology was adopted. Rather than being consigned to a mode of pure imagination, a speculative methodology acknowledges that the future is always in the making (Savransky et al., 2017). This was brought into conversation with a matrix of 'concrete' data: that which constitutes the discursive practices that accompany social futures (Urry, 2016) and (re)shapes them through their very occurrence. With these observations in mind, I now consider the use of a speculative methodology, turning to consider the matrix of 'concrete' data later in the chapter.

4.3.1 Towards a Speculative Methodology

As previously noted, the research at hand posed some challenges beyond those typically considered as part of the research process. Specifically, these issues centered around how to study a topic that is both temporally and spatially inaccessible, precluding me from accessing the sites of interest and experiencing the material conditions of the field: both due to asteroid mining having yet to take off and having no means of exploring an asteroid myself. The answer to this was the adoption of a speculative methodology. This recognises that a series of discursive practices are at play that (re)shape social futures (Urry, 2016): actively engaging

[89] Given due consideration later in this chapter.

with these discursive practices and the ideological undercurrents that (re)structure debates of Outer Space futurity and the socio-political-material relationships these inform (Arendt, 1958: Kearnes and van Dooren, 2017: Redclift, 2006: Valentine, 2012). Indeed, engaging with the imaginative or speculative has arguably become a new intellectual agenda amongst many fields, especially STS (McNeil et al., 2016) but with increasing focus in other areas (Tutton, 2017). These increasing engagements with the speculative have led to the development of a concept of the 'imaginary' that challenges the opposition between science and imagination (ibid), recognising that they are better conceived of as co-constitutive (Tutton, 2017: Urry, 2016).

Attempting to research the future through examining discursive practices and their attendant discourses does not automatically allow unfettered speculation to occur. Aside from being informed by and through practices (thereby curtailing rampant speculation), the dominant response to futures largely privileges a "business-as-usual" approach that submits speculative futures to the same logics, rationales, and habits that govern the problematic present (Savransky et al., 2017). Here the issues of disimagination and its subtending a state of capitalist realism (Didi-Huberman, 2008: Giroux, 2014: Fisher, 2009) become particularly salient in their ability to maintain a neoliberal mode of governance: one that seeks to measure, organise, tame, and influence people (Savransky et al., 2017) through the active silencing of futures that decenter capitalism, Eurocentrism, and terracentrism. Due to this neoliberal coercion of the future, speculation has come to be tied to negative connotations such as speculative finance and its attendant crashes (Savransky et al., 2017).

However, whilst there are negative connotations associated with 'speculation', completely abandoning its use runs the risk of an obscurantism that denies a decent

recognition of – and engagement with – other modes of speculation that disrupt normative discussions of futurity. Recognising this, we may consider speculation as a struggle against probabilities (ibid): as a means by and through which the *de facto* future of capitalist realism may be disrupted and challenged, decentering those futures that take for granted capitalism, Eurocentrism, and terracentrism. Understanding speculation as such led to an engagement with Ethnofuturism: imaginative practices that do not necessarily take a White, settler colonial history as their starting point. Indeed, speculation is fundamental to conceptualisation, allowing us to question reality, (re)shape spatial conceptions, or express alternatives (Dunn, 2018), all of which are key aspects of this research. Furthermore, it has been noted that speculation actually allows for the cultivation of a "deep empiricism": one concerned not only with isolated and discrete facts but also their relations and focus of togetherness, where the world is always in the making and both the human and other-than-human can be accounted for (James, 2011: Savransky et al., 2017: Whitehead, 1967). Indeed, rather than considering speculation as unfounded or conjectural, a speculative methodology recognises that all future-oriented thinking involves assumptions of the nature of futurity, our ability to think and know in relation to it, and that it is necessarily (re)constituted through contact with the material world it is often said to bypass (Diprose, 2017: Savransky, 2017).

Indeed, speculative research has been used to great effect in several research areas, all of which have allowed for the (re)conceptualisation Dunn (2018) advocates. Valentine (2017) uses a speculative approach to great effect in their deliberations on the habituation to *one-g* and its ramifications in (re)defining humanness. As they note in their work, a speculative approach requires a deep engagement with the implication of respondents' material labour and imaginative talk rather than total ethnographic accounts of them (ibid). They also note that whether or not respondents' speculations come to pass, these should be

considered in their own terms, not simply due to the vast amounts of capital and labour expended to realise these projects but because they allow new insights into theorising humanness (ibid): or, in the context of this research, theorising human-material relations. Speculative research has allowed numerous theoretical deliberations to be conducted: Messeri (2016) has used this to explore how data on exoplanets is 'translated' and (re)articulated into artistic conceptualisations in discursive practices of place-making throughout the universe: Tutton (2017) has utilised speculation when examining the Mars 100's attitudes towards Mars as a potential future home: and Clark and Szerszynski (2020) have used speculation in their discussions of multiplanetarity *vis-à-vis* social thought in the Anthropocene. Speculation is not consigned to the field of Outer Space studies but has been used elsewhere also. Childs has used this to great effect in their exploration of the issues and socio-political-material relations that accompany deep sea mining (2019: 2020). They have used this in conjunction with 'concrete' data as a means of exploring the discourses at play within deep sea mining (Childs, 2019) and to 'perform' a critique of blue growth that rendered visible alternative descriptions of the geopolitical imagination of the deep sea (Childs, 2020).

These works highlight the potential posed by a speculative methodology: one that allows for (re)conceptualisation and thinking outside and beyond "business-as-usual" futures. It provides a space wherein and whereby alternative social futures may be espoused and the full gamut of hopeful (or hopeless) futurity can be explored. Crucially for this work, it enabled an exploration of a research site that is both spatially and temporally distant and out of reach, operating as a gateway through which this work could be conducted and where the futures of capitalism, Eurocentrism, and terracentrism could be decentered.

4.3.2 Rethinking Ethnofuturism as Method?

Having discussed the role of speculative research within the context of this thesis, I turn now to briefly revisit Ethnofuturism. Whilst Ethnofuturism has been explored in the preceding chapter through its conceptual contributions to this research, this is not the full extent of Ethnofuturism's remit nor application. It can be rethought and applied as a method in itself, complimentary to – or a part of – the speculative research process and reviewing the speculations that we are presented with. Indeed, given that all future-orientated forms of thinking involve a medley of assumptions (Savransky, 2017) and that speculative thinking will always have some manner of contact with the material world it purportedly bypasses (Diprose, 2017), Ethnofuturism demands that we critically account for both the assumptive and material conditions that shape and inform the speculations we encounter in the research process. More specifically, these assumptive and material conditions *vis-à-vis* an engagement with Ethnofuturism stem from its simultaneous engagement with past, present, and future: blurring temporalities to (re)shape speculative futures.

Presently, it may seem that Ethnofuturism here is operating as more of a methodology than a method itself. That is because the distinction between Ethnofuturism's conceptual contributions and capacity to operate as a method are by no means clear-cut. Conceptually, Ethnofuturism allows for the contestation of normative modes of imagining the future and the *de facto* histories and material conditions these draw upon (Bould, 2007: Quan, 2017). However, Ethnofuturism – in its innumerable guises – is just as concerned with praxis as it is with theory, if not more so. Whilst the term operates to blur the archaic and indigenous with the cosmopolitan and technological (Hennoste, 2012: Kolcheva, 2015) to counter the active erasure of various peoples' histories, presents, and futures through the disimagination process (Didi-Huberman, 2008: Giroux, 2014), it operates towards a more tangible and

practical end. Specifically, Ethnofuturism – as an artistic and political act – seeks to emphasise 'transformation rooted in the present world' (Quan, 2017; p.191). Consequently, Ethnofuturism is as much a tangible action as it is a conceptual act. Understanding Ethnofuturism as such underscores its salience for speculative research in the context of this project: as a series of acts that can disrupt normative assumptions, thinking beyond capitalist futures, decentering Eurocentric discourses of futurity, and even thinking with and beyond the Earth.

Indeed, understanding Ethnofuturism as such renders it as much a *practice* as a concept. To arrive at Ethnofuturism as a *method* – and one particularly befitting the research aims of this project – requires us to understand it within the context of the act of researching itself. Given this work's focus on decentering capitalist futures, Eurocentric imaginaries, and thinking beyond the Earth, Ethnofuturism was engaged as a method due to its ability to spur on and subsequently explore speculative discussions. Ethnofuturism was drawn upon as a method during interviews with both NSE actors and Ethnofuturists alike. Once our conversations had covered the substantive points of asteroid mining and its associated socio-politics – themselves iterations of speculation – interviewees were asked to engage in a set of deliberate imaginative acts that drew from, and engaged with, Ethnofuturism. Interviewees were asked to imagine several scenarios: what they hoped would happen with asteroid mining; what their worst-case scenario would be and; what they thought would likely come to pass. This imaginative 'game' provided interviewees with a chance to create and discuss their own future hopes and fears, opening a new site of speculative exploration and discussion. Invariably, respondents utilised various historical and cultural analogies – drawing upon their own culture as well as others. This provided opportunities to unpack some of the underlying assumptions within their speculative futures: opening the discussion to

possibilities outside of or beyond capitalism, Eurocentrism, and sometimes the Earth. At other moments, it provided an opportunity to challenge some of the normative assumptions used, opening sites of discussion around ideas of 'inevitability' and why this was believed to be so.

Through engaging with Ethnofuturism in such a way, it can be regarded as a method in itself; one that complements speculative research. When undergoing 'fieldwork', it provided a means by and through which various areas could be opened up for discussion that would have otherwise been missed or an awkward point of disjuncture to the discussion at hand. It also helped generate more data relating to speculative futures than engaging with art and literature alone may have provided and enabled the conversation to turn to historical and cultural specificities that a general conversation on asteroid mining would not have readily allowed. It enabled the 'archaic and indigenous' to be brought into conversation with the 'cosmopolitan and technological' (Hennoste, 2012: Kolcheva, 2015) and subsequently unpacked in the course of the interviews, being made explicit where this may have only been implicit without the use of Ethnofuturism as a method. Crucially, it allowed for a more thorough conversation around speculative futures and the (de)centring of capitalism, Eurocentrism, and terracentrism: key aspects of this research.

4.4 Terracentric Constraints

Before moving on to a focused discussion of the more 'traditional' methods used to generate the matrix of "concrete" data noted above, I wish to briefly discuss another challenge posed by this research. In this instance, the challenge is not simply located within the method of generating data itself (though it was present there also) but has been present throughout the subsequent discussions. Specifically, the issue lies with the very acts of attempting to think through and discuss the manifold complexities present beyond the terrestrial. This may

appear at first to relate to the notion of 'mess' within social science research – something endemic within the social sciences that is exacerbated through attempting to discuss that which is 'complex, diffuse and messy' (Law, 2004). Whilst discussing Outer Space and its attendant environs increases the complexity and subsequent 'mess' that comes with this, it departs from typical conversations of mess in the social sciences in two discrete ways: through moving outside of the terrestrial and its attendant framing(s) of onto-epistemological concerns and Outer Space being comprised of multiple, distinct, and shifting components that confound and elude simple description and understanding from a terracentric perspective. Indeed, whilst this research has generated multiple data, this does not necessarily allow us to coherently engage with the ephemeral, indefinite, and irregular (Denzin, 1970: Law, 2004: Mason, 1996: Silverman, 2003: 2011), all demands made when researching Outer Space and engaging with speculation.

The challenges posed by terracentric onto-epistemologies and associated discussions are akin to those of anthropocentrism. 'Normative' anthropocentric arguments posit that nothing but human beings have moral standing (Attfield, 2011) wherein the preservation of the environment is frequently based on the promotion of human interests or goods (Katz and Oechsil, 1993). In a similar fashion, there is a 'normative' set of terracentric arguments also. Here, nothing but the Earth – or 'terran' – has moral value, debates being framed around issues and interest that are of concern within a planetary context. However, conceptualising and debating Outer Space futurity demands that we attempt to account for issues that are of concern in a *multiplanetary* context and begin to take seriously the moral, ethical, and philosophical deliberations that come with this. This latter dimension has led Helmreich (2012) to discuss what they call 'Extraterrestrial Relativism', wherein they note that "[a]dvocates of privatised space travel [ ], of asteroids as destinations for exploration [ ], and

Singularitarians [ ] often conjur their visions of extreme futures with respect to very human concerns" (p.1136). This is not a monolithic entity but is itself multifaceted, many in the NSE sector speaking from positions of intersectional privilege, rendering popular modes of extraterrestrial relativism "not just a humanist point of departure, but an elite vanguardist one" (ibid.). Whilst we may never truly escape terracentric modes of thought – being, as we are, (re)shaped and (mis)informed through a set of singular planetary experiential knowledges – working through problems posed by terracentrism operates as a fertile area by and through which to begin (re)thinking and taking seriously a series of moral, ethical, and philosophical questions that may otherwise be discounted or missed entirely. Indeed, Valentine (2017) uses the shifting contexts of gravity in off-world environments to begin an engaging philosophical interrogation of humanness and how this has been informed through the context of '*one-g*'. Similarly, Pankhurst and Jeevendrampillai (2021) have begun thinking through matters of (micro)gravity and its implications for emotion and embodiment, something that has not been considered within a terracentric framework.

The constraints of terracentric thought pose a significant challenge to conceptualising the issues of Outer Space and its attendant study and debates. Indeed, Latour (2017) goes so far as to argue that we need to 'reterrestrialise' our thinking, arguably oppugning the Social Studies of Outer Space for more 'Earthbound' thought. However, whilst much valuable work has been done to convey the complexities of planetary thought (e.g. Clark, 2011: 2013: Clark and Szerszynski, 2020: Clark and Yusoff, 2017: Johnson et al., 2014: Rowan, 2015: Szerszynski, 2018: Yusoff, 2013a: 2013b: 2015: 2017), this literature is a tentative first step in addressing the issues of terracentrism, being grounded as it is in *planetary* as opposed to *multiplanetary* thought. Thus, whilst terracentrism has posed a challenge to conducting and subsequently discussing this research, it is not something that we should attempt to bypass or negate.

Instead, it is a site whereby some of the most interesting speculative deliberations may begin and ensuing moral, philosophical, and practical considerations enlivened. Thus, just as debates on planetary dynamism can instigate new modes of thought and critical engagement (Clark and Szerszynski, 2020: Rowan, 2015: Szerszynski, 2018: Yusoff, 2018), turning to the multiplanetary and interrogating terracentrism promises to enrich these debates even further.

4.5 A Multiple Method Approach

A speculative methodology was used as it allowed an engagement with a research topic that is both spatially and temporally inaccessible, and for a "deep empiricism" that goes beyond a simple engagement with isolated and discrete facts to examine their relations (Savransky et al., 2017). However, this does not negate the need to examine the discursive practices that (re)shape social futures (Urry, 2016) from which the speculative arises and is grounded in. Given this, a matrix of "concrete" data was generated through a multiple method approach: consisting of 20 in-depth interviews; 87 SF novels, short stories, and films; participant observation of 3 NSE conferences (generating fieldnotes, collecting advertising materials and 171 photographs, and attending >50 talks); 4 national asteroid mining policy documents being analysed; grey literature on asteroid mining being collected and used; website materials from DSI and Planetary Resources; concept art; and email correspondence with asteroid mining companies. This approach was decided for a number of reasons that stem from both methodological theory and the specific needs of the research project. I will briefly outline three broad reasons for a multiple method approach before discussing some of the specific requirements of this project.

Firstly, the topic of study in part defines the methods used (Robinson, 1998: Silverman, 1985: Straus, 1996). Asteroid mining – and the New Space Economy more broadly – operates over and through multiple sites and media. Adopting a single method would have resulted in only a partial understanding of the research topic being produced, failing to engage with the multiple and variegated means through which asteroid mining is (re)articulated. Indeed, a multiple method approach can assist in understanding social complexity (Eyles, 1988), something this project demanded due to the diverse, multi-media context within which the New Space Economy and asteroid mining operate.

Secondly, there is currently a relative dearth of literature on the broad field of the Social Studies of Outer Space (SSOS). This lack of literature is even more pronounced when we begin to focus more specifically on asteroid mining. Without such literature, there was little existing research with which to position myself within an existing 'field'. Consequently, the research required more information than a single method could produce to allow the project to become situated: a larger matrix of data allowing a 'holistic view' (Chamberlain et al., 2011: Darbyshire et al., 2005) within which my focus could be 'triangulated' (Bradshaw and Stafford, 2005: Dunn, 2005: Eyles, 1988: Valentine, 1997). Indeed, work in the SSOS has yet to engage with any qualitative empirical work regarding asteroid mining, meaning a multiple method approach promised to be particularly fertile and conducive towards answering the questions posed by this research. Where asteroid mining has been discussed, the approach has been either completely theoretical (e.g. Kearnes and van Dooren, 2017) or focused solely upon policy frameworks and analysis (e.g. Fox, 2016: 2019). More broadly, only a few papers have engaged with qualitative research to any meaningful extent, though these have dealt with topics as diverse as the Mars One project, exoplanet studies, or terrestrial operations (see Tutton, 2017: Messeri, 2016: Redfield, 2000). Given the present state of

qualitative research on asteroid mining, it seemed prudent to produce a corpus of data to work with and through.

Finally, given the lack of detailed research on asteroid mining – especially from a qualitative perspective – multiple methods allowed for a certain level of 'creativity' demanded by the project. Producing a matrix of data allowed for spaces wherein speculation's "deep empiricism" could function. This allowed for the scope and depth of the data generated to be extended, producing a rich data set within the time constraints of the project where different modes of data could be brought into conversation with one another, increasing the data's versatility and reliability.

Alongside these three broad reasons for utilising a multiple method approach are some project-specific rationales. I knew from the outset of this research project that I would be dealing with groups that were both small and hard to access. Given the potential accessibility issues posed by my research targets (constituting 'Elites'[90] in various ways), a multiple method approach seemed prudent. This approach reduced both the pressure and risks of using a single method in the context of small group size and issues of access, allowing different data sets within the matrix to 'sure up' and complement one another. Furthermore, I was dealing with 'Elites' and a multiple method approach has been advised by various elite studies scholars. It has been suggested that when engaging 'Elites' in research that an analysis of press releases/public statements and participant observation be used alongside interviews

[90] The term 'elite' has garnered much debate throughout the history of 'elite studies' (Frankenberg, 2002: Gilbert and Sklair, 2018: Hart, 2002: Moyser and Wagstaffe, 1987: Shore, 2002). To delve into this topic thoroughly is beyond the remit of this thesis and would require a section unto itself – something that the thesis wordcount curtails. For the sake of the term's use here, I take 'elite' to simultaneously mean its *de facto* usage in 'normal language' (Frankenberg, 2002), those who are able to influence the direction of society to some degree or another (Moyser and Wagstaffe, 1987), and "as part of the group life of a society, or as participants in a wider political process" (ibid ; p.4).

to negate potential issues of lying and omission (Moyser and Wagstaffe, 1987: Shore, 2002). This observation gave further impetus to use a multiple method approach as the different sets of data could be used to 'triangulate' my research should it be potentially misled through this lying or omission (Bradshaw and Stafford, 2005: Dunn, 2005: Eyles, 1988: Valentine, 1997). This allowed for a dataset to be generated that incorporated Winchester's (2005) three 'modes' of research (the oral, textual, and observational), making the research more robust and versatile than a single method alone would have permitted.

Consequently, a multiple method approach was adopted in response to the demands of the research project at hand, producing a matrix of 'concrete' data that could engage with the discursive practices of social futures (Urry, 2016) and permit the "deep empiricism" of a speculative methodology (Savransky et al., 2017). This approach generated data spanning the three 'modes' of qualitative research (Winchester, 2005) that could be brought into conversation with one another to spur conversation and insights that singular methods alone would not allow for. I will now briefly discuss each of the methods used in turn, beginning with interviews and moving on to textual analysis, participant observation, and grey literature in turn.

4.5.1 Interviews

Of the methods outlined above, I turn first to consider interviews. I knew from the outset that it would be difficult to secure interviews due to the small population sizes of the asteroid mining sector and Ethnofuturist community, but this method posed distinct advantages within the context of this research. It allowed me to generate information from actors directly and actively engaged in the processes I sought to study: both those involved in advocating for asteroid mining and those seeking to disrupt and unsettle the *de facto* narratives of

capitalism, Eurocentrism, and terracentrism. Moreover, securing interviews enabled a more in-depth understanding of the research topic than inference from the other methods alone would allow – I cannot ask a billboard if it thinks the future it advertises is feasible or just. Aside from these practical aspects, interviews had an advantage of being a well-established method to rely on, some 90% of social science research using this method (Baxter and Eyles, 1997: Briggs in Holstein and Gabrium, 1997: Janghorban et al., 2014: Kitchin and Tate, 2000). Whilst a seemingly mundane reason, it allowed for some 'stable' data generation amongst the more adventurous aspects.

Potential interviewees from the NSE were identified through engaging with company websites and researching NSE conference speakers/attendees. Those who were deemed appropriate to the research – either through their active involvement in an asteroid mining company or through their advocating for asteroid mining in these spaces and public forums – were contacted either via email/company websites or approached directly at conferences. To recruit Ethnofuturists, the authors of various texts used in this research and Ethnofuturists featured in news articles and blogs were approached either through contact forms on their fan sites or via their agents. In one instance, serendipity meant that I met an Ethnofuturist author at one of the conferences by chance. Participants were recruited through three techniques. Firstly, I used opportunistic sampling: through attending New Space conferences I was able to meet NSE actors that were otherwise impossible to reach and I used publicly available email addresses. Secondly, I used convenience sampling: I could only interview participants that I could gain access to. Finally, I used snowball sampling: relying on interviewees connecting me with other people. Through this combination, I was able to conduct 24 interviews (however, 4 were discounted: 3 did not return consent forms and another withdrew as their company would not permit them to go 'on the record'). More

empirically-driven researchers may flinch at this as it appears to be a 'small sample size' with "only sizeable samples [holding the] promise of validity" (Crouch and McKenzie, 2006; p.484). However, this was not the sole method used to generate data, interviews producing valuable insights through being situated within a matrix of data and through the 'labour of conceptualisation' (Baxter and Eyles, 1997: Crouch and McKenzie, 2006: Eyles, 1988: Lincoln and Guba, 1986). Moreover, the topics discussed were both speculative and experiential: thus, there was no need for interviews to be 'representative' of either group. Indeed, the aim of interviews is not to be representative, rather their aim is to "understand how individual people experience and make sense of their own lives" (Valentine, 1997; p.111). With these points in mind, the number of interviews conducted were sufficient given the multiple datasets generated.

These interviews were conducted through several media. Specifically, I used a combination of face-to-face, Skype/FaceTime, and email interviewing. This was done due to interviewees being dispersed across large areas and the time constraints of the project disallowed the 'slow' research of travelling to each respondent[91]. Where digital modes of interviewing were used, respondents were given the option of video calling or emailing correspondence as I was mindful that some interviewees had childcaring responsibilities and busy schedules, so the flexibility allowed me to conduct interviews whilst being respectful of respondents' other commitments. Each of these modes of interviewing came with their own pros and cons for the research process. Incorporating digital interview methods allowed for geographical distance to be overcome (James and Busher, 2006: 2007: Janghorban et al., 2014). Video calling enabled 'real time'/synchronous interviews to be conducted over large

[91] We could also query the ethics of travelling to each interviewee given the vast quantities of CO_2 involved in taking multiple plane journeys.

distances and I could still pick up on facial expressions and respondents' tones, all of which can be useful cues of where to take the conversation (Janghorban et al., 2014). A drawback of this media is that I was not necessarily able to see – and "read" – participants' body language as easily as I could in physical meetings and these interviews were reliant on access to the necessary technologies and a steady internet connection (ibid). Similarly, interviewing via email brought other advantages than a 'traditional' interview format provides. As with video calls, vast geographical distances were no longer an obstacle. Additionally, this allowed for asynchronous interviewing, allowing respondents with significant time constraints and commitments to still participate (James and Busher, 2006: 2007). Furthermore, it allowed me to revisit what had already been 'said' in the interview and pose questions based on further reflection (James and Busher, 2006) that I may not have asked in a physical interview due to the faster pace. Moreover, this 'slower' interviewing allowed a more contemplative response from interviewees (James and Busher, 2007). As with any method, emails have their limitations also. Specifically, they are disembodied, meaning I could not read a participant's body language, facial expression, or tone, meaning certain cues may have been missed. However, despite these potential drawbacks, email interviewing allowed me to speak with respondents that may otherwise have had to decline.

Given the potential issues of digital interviewing, the chances of 'mishearings' may have increased. 'Mishearings' are the result of ambiguous utterances by interviewees who speak with the assumption that there is one correct interpretation of what they have said, ultimately defined by the speaker themselves (Bilmes, 1992). However, this is seldom the case: all qualitative data being interpreted through a multitude of frameworks (Denzin, 1970: Kitchin and Tate, 2000: Silverman, 1985: 2003: 2011: 2013). With the disembodiment of the interview process removing certain markers such as body language and tone, 'mishearings'

may have been more likely. However, this is an issue present within 'traditional', physical interviews (Bilmes, 1992) and I decided that offering interviewees a range of media through which to 'meet' was beneficial to the overall research process and respectful of respondents' time constraints and commitments, giving interviewees more agency in the research process.

4.5.2 Textual Analysis

The second method used in generating 'concrete data' was textual analysis. This generated qualitative data of textual and observational modes (Winchester, 2005) through collecting and analysing multiple resources. Texts were initially identified through general searches for Ethnofuturist texts on the internet, the search becoming more refined through using resources such as the *Science Fiction Encyclopedia, Goodreads,* and literary review blogs. Upon identifying potential texts, I then looked up their reviews, found blog pieces on them if there were any, and searched to see if there had been much written around the author and particular work in question. Following this research into potential texts, I then ordered those that seemed the most promising and proceeded to read and analyse them as part of the research process. To generate NSE sector data, I accessed company websites and took copies of their pages, went through their 'news' sections for relevant information, and created news alerts for asteroid mining companies and asteroid mining more generally to keep abreast of the latest developments and to ensure that I was aware of any new material relevant to the course of this research. The materials collected included company press releases; asteroid mining company websites; images/concept art; photos from fieldwork; SF literature; and advertising materials. Whilst a productive method in itself, textual analysis was used in conjunction with interviews to strengthen and diversify the data generated and in recognition of asteroid mining advocates and critics operating over and through multiple media. Not only

did incorporating textual analysis into the data generation process produce a richer matrix of data, it also provided a means through which to fill gaps that could not otherwise be known (Cope, 2003) and responded to Moyser and Wagstaffe's (1987) advice[92].

Indeed, textual analysis is an incredibly useful means of engaging with qualitative data generation and has greater use still when undertaking a speculative method approach, constituting another dimension of discursive practices that (re)define social futures. Whilst we may consider the 'field' as something multiple and (re)constituted through a complex matrix of decision-making processes (Katz, 1994), we can take this further: the field being redefined as neither a 'place' nor an engagement with a 'people' but as a political artifact that can be read in multiple ways (Nast in Aitken, 2005). This (re)constitution of the 'field' coupled with a necessary focus on the discursive practices that inform futurity and their attendant speculations underscored the need to engage with texts and their subsequent analysis. Reinforcing this position further was that texts have become so prevalent that society and contemporary culture has come to be defined by some as an imaginative collage of mixed-media (Aitken, 1997: 2005: Driver, 2005) and the diverse range of material that now constitutes 'texts': new materials being 'read' that contribute to the (re)construction of societal (counter)narratives in variegated ways (Aitken, 1997: 2005: Driver, 2005: Fairclough, 1992: 2001: 2003: 2009: Mayr, 2008). Given that the futures of asteroid mining and their attendant speculation frequently occur over and through multi-media, collecting this information, analysing it, and situating it within a larger data matrix seemed prudent to producing a well-rounded and informed conversation around asteroid mining.

[92] Noted in Section 3.5: 'A Multiple Method Approach'.

Moreover, recognising texts as a foundational source through which futurity is (re)shaped gave them further salience to a speculative method. Texts become more than an amalgamation of writings and readings through their ability to shape (un)popular discourse. Through regarding texts in this manner, they become a gateway through which to theorise the workings of power and how hegemonic systems are perpetuated and challenged (Aitken, 2005: Crang, 2005: Driver, 2005: Fairclough, 2001: 2003: 2009: Horton and Kraftl, 2014: Mayr, 2008: McGeachan and Philo, 2014: Nunan, 1993): crucial to this work's focus on decentring capitalism, Eurocentrism, and terracentrism. This was also noted by an NSE interviewee, who explained that some of the best thinking – or "deep dives" as they called them – on speculative Outer Space futures is to be found in Science Fiction. Not only does fiction provide a gateway into "deep dive" speculation, it can function as a 'critical mirror' of society; exploring and destabilising normative assumptions of everyday life (Horton and Kraftl, 2014). Thus, SF can operate as a vehicle whereby new technologies and alternative futures can be introduced and advanced (Birtchnell and Urry, 2013: Kirby, 2010). Through recognising this, SF was critically engaged as a site where counternarratives to an otherwise hegemonic socio-political futurity could be introduced and advanced, disrupting and reimagining these relations and their attendant futures (Birtchnell and Urry, 2013: Horton and Kraftl, 2014: Kitchin and Kneale, 2001: Kneale and Kitchin, 2002: Stingl, 2016). Engaging with SF along with the other mixed media texts allowed for the voicing and exploration of various histories, normative and critical engagements with the present, and the (re)creation of futures that this speculative research was contingent upon. This allowed me to explore how different histories were drawn upon and blurred with the future to produce (counter)narratives of what is acceptable, expected, and normalised as a future 'inevitability': confounding or confirming

the disimagination process and decentring *de facto* futures that orientate themselves through capitalism, Eurocentrism, and terracentrism.

4.5.3 Participant Observation

The third method used in producing the matrix of 'concrete data' was participant observation. This method enabled me to access NSE actors through opportunistic sampling and produced more data itself. Specifically, to collect this data I attended 3 NSE conferences where I was able to access >50 talks, hear conversations within and between these proceedings, generate 171 photographs, collect advertising materials, and make extensive fieldnotes. All of this data was added to that generated through interviews and textual analysis, enriching the dataset and subsequent conversations further.

Whilst participant observation is typically regarded as a defining method of cultural anthropology (DeWalt and DeWalt, 2011: Spradley, 1980), it has been increasingly used in qualitative research in a variety of fields (Atkinson and Hammersley, 1994: Kawulich, 2005). I incorporated this method into the research process as collecting observational fieldnotes from conferences was opportune – I was going there to contact respondents anyway – and NSE conferences are currently an untapped field site in SSOS. With both of these aspects in mind, I decided to use my attendance at these conferences as an opportunity to diversify the corpus of data I was collecting and to experience some of the 'black box' of processes and conversations that happen at NSE gatherings. In conducting this 'fieldwork' I was able to actively observe some of the NSE sector: registering, recording, and interpreting the interactions and practices that occurred at these sites (Schwartz and Schwartz, 1955), participating in activities and asking questions of the actors, artifacts, and practices therein (Becker, 1958: Dewalt and DeWalt, 2011: Spradley, 1980). Having gone through this process,

I recorded my interactions, observations, and thoughts as fieldnotes for consideration and interpretation later in the research process (Kawulich, 2005: Spradley, 1980) and to bring these thoughts into conversation with the rest of the data generated in this work.

A longstanding debate regarding participant observation surrounds 'proof' of the data generated, in part due to the difficulty of articulating the processes of data generation and analysis[93] (Becker, 1958: DeWalt and DeWalt, 2011). Given this tension, I will briefly elaborate on how participant observation was conducted, increasing the 'rigour' of accounting for the research process as Baxter and Eyles (1997) have called for. The participant observation for this research consisted of attending three conferences with relevance to the NSE: one in Europe (the *ESPI* conference), one in India, and another in the USA (hosted by the *Space Frontier Foundation*). Due to complications with the conference in India, much of this information was discounted from the research project. Whilst this data was excluded, the *ESPI* and *SFF* conferences produced a sizeable amount of material for the project. During all of these conferences I was open about my purposes for being there; my attendee badges cited my occupation as 'researcher' and I answered queries honestly. Adopting this approach avoided the potential ethical complications associated with covert observation and provided the opportunity to have other attendees approach me with queries and begin conversations that way instead of my having to initiate contact and conversation. This provided a convenient means of asking attendees if they would be interested in being interviewed. This approach enabled me to recruit all of my NSE interviewees and an Ethnofuturist also. Fieldnotes were made during and between talks; both on the talks themselves and the conversations that took place around these. I adopted a mixed approach to the fieldwork, shifting between 'passive'

[93] We may think back to section 3.4's brief discussion of 'messiness' here.

and ‘active’ participation as and when appropriate. Passive observation was used during talks and active participation during my interactions with attendees and when asking questions of speakers to clarify research-relevant points. This approach allowed for flexibility within the ‘fieldwork’, enabled NSE actors to be recruited for interview, and generated fieldnotes and photographs that enriched the corpus of data generated in this project.

4.5.4 Grey Literature

The final method used to compile a matrix of ‘concrete data’ was the collection, analysis, and incorporation of grey literature. Whilst this shares much overlap with the preceding discussion on textual analysis – the grey literature constituting ‘texts’ itself – I wish to briefly outline some of the specific details behind its use in this research.

Whilst substantive data was collected through the methods outlined thus far, I chose to incorporate grey literature into my research for a number of reasons. Using grey literature provided another route by and through which to explore and verify claims (Moyser and Wagstaffe, 1987) and provided contextual grounding following interviews and some texts. Indeed, grey literature – “material produced and published by organisations without recourse to the commercial or scholarly publishing industry” (Lawrence et al., 2014; p.2) – provided information that was crucial in filling gaps in research data (Cope, 2003) and allowed for the “deep empiricism” of the speculative method to go further. This grey literature was not only used to fill gaps but was brought into conversation with the other data generated to enliven both the conversations and subsequent theorisation. This was particularly fruitful when considering the materialities of asteroids and the ensuing issues of waste that was frequently elided in interviews: publicly available databases providing information on asteroids’ volume, dimensions, and material composition, all information that could push the speculative

dimensions of this research further. Furthermore, engaging with grey literature in this manner allowed me to (re)interpret the data and use it to new ends, thereby generating new 'knowledge' and enabling a more substantive conversation than data from any other method alone would have permitted. Consequently, whilst seemingly a tangential aspect of the textual analysis, grey literature enriched the data generated and spurred on the conversation where its absence would have otherwise curtailed this.

4.6 Techniques

Having outlined and accounted for the methods used throughout the course of this research, I turn now to briefly account for the techniques used in analysing the generated data. As previously noted, data was generated through a variety of methods due to the small groups being accessed and to avoid the pitfalls of engaging with Elites outlined by Moyser and Wagstaffe (1987). This multiple method approach allowed me to generate a corpus of data comprised of oral, visual, and textual media (Winchester, 2005). Having collected this data, it was drawn together and subsequently coded through thematic analysis. This process was undertaken multiple times for a couple of reasons.

Firstly, I opted to approach the data with as open a mind as possible. During initial readings, I highlighted anything that I thought to be of note or interest, whether or not it 'spoke' to any of my research questions. This approach was adopted as keeping an open mind at this stage of the analysis allowed the data to 'speak' (Cope, 2003) and for a variety of codes to emerge within each set of data. This process also acknowledged and permitted the reflexive relationship involved in the coding/analysis of material. Specifically, it meant that as various themes or ideas emerged from the data, I could then go back to the previous materials and re-analyse them in light of these new themes (Cope, 2005). Moreover, returning to the

data and (re)analysing it multiple times allowed for a 're-familiarisation' with the materials collected (Crang, 1997) which subsequently allowed me to become more deeply embedded within the data itself and draw out new and connecting themes, refining or reconsidering these upon each visit. Alongside this process of 're-familiarisation', there was also the more personal dimension: the aforementioned matter of my class positionality and some of the discomfort this brought to my time in 'the field' encouraged me to return to the data[94]. This reflexive process, wherein the data was allowed to 'speak' for itself (Cope, 2003), enabled new themes to emerge and new questions to be asked. Indeed, this process is what drew questions of waste to the fore and led to my contacting some of my interviewees and asteroid mining companies to gather further information on this theme.

Secondly, through producing a series of codes across the various media of data that I had generated, I was able to reduce the size and scale of the data set I was working through (working now with a series of 'codes' rather than raw datasets), organise the data around these specific themes, and was then able to engage in 'deep empiricism' through the analysis these codes permitted (Cope, 2005). Indeed, through thematically coding my data I was able to identify points of congruence within and between the various modes of data that I had generated – themes acting as bridges between datasets that made their connections more obvious than they may have been otherwise (Cope, 2003: Jackson, 2001).Through making these connections via thematic coding, a large and potentially unwieldly dataset was whittled down and the substantive themes that make up the proceeding chapters of this thesis were identified and brought together.

[94] See subsection 4.2.2 for further discussion.

It is worth mentioning here that whilst a large number of photographs were taken at field sites, they do not feature much throughout the course of this thesis. This is partly due to their speaking less to the substantive points within this thesis: instead, they are better suited to address topics that are tangential to those addressed throughout the forthcoming chapters. However, whilst they may not feature in what follows, photographs were incredibly useful when analysing the data generated. Similar to how analysis allows for the 're-familiarisation' of material, photographs enabled me to (re)situate myself when analysing materials through their providing context for my fieldnotes. Whilst fieldnotes are themselves a valuable mode of data, having photographs of my field sites and the spaces wherein these notes were made were incredibly helpful as a reminder of the spaces I had been in and for some of the context(s) that led to the notes being made in the first place. Consequently, the inclusion of these photographs during the analysis stage were deeply beneficial to the process, despite their notable absence in the proceeding discussion.

Following this process of repeated reflexive analysis, a set of themes emerged through which multiple conversations could be had. At this stage, I had to decide which themes to engage with for inclusion within the thesis and which to set aside, an inevitable part of the research process whereby the researcher structures what is and is not to be discussed within their research (Crang, 1997: Eyles, 1988: Winchester, 2005). Here, several factors influenced my decision of which themes were brought forward. Firstly, there were the research questions that I had posed at the outset of the research – something that itself helps to structure the research process (Cope, 2003). Here, I simply considered which themes spoke most directly to these questions. Secondly, there was the strength of each theme itself, i.e. which themes came up the most and consequently had more data supporting them. Thirdly, there was the consideration of how themes 'spoke' to *each other*. Whilst there were some

‘strong’ themes present following repeated reflexive analysis, some themes were ill-suited to creating a coherent discussion, pulling the conversation in different directions. Consequently, complimenting themes were chosen around which a discussion could be held. Finally, there is the simple influence of what I as the researcher and author found interesting – which themes was I happy to sit with and consider at length and which themes were best left for another day.

Having considered the means by and through which the data generated during this research was analysed and ordered, I turn now to the first discussion chapter this process enabled.

Chapter 5: The 'Final Frontier': Imaginaries and Material Relations

5.1 Introduction

This chapter is the first of three discussion chapters. It discusses the materiality of asteroids and how the composite materials are understood, articulated, and inform the socio-political-material relations (re)forming around asteroid mining and extraterrestrial extraction more broadly. I begin by considering how Outer Space is being politicised and (re)cast as a new 'frontier', attracting speculation and investment, along with a host of issues. The conversation then turns to consider how asteroids and their attendant materialities (re)create relationships with them. The final section discusses the ways asteroids and extraterrestrial extraction trouble geographical thought, being bound up with (extra)planetary forces that remain fairly consistent in a terrestrial context.

This discussion chapter draws primarily from the grey literature collected and participant observation notes, with some interview data (interview data is used more throughout Chapters 6 and 7). This chapter is more conceptual in its content than the proceeding two, exploring how asteroids are being understood and articulated, pointing to the ways Outer Space disrupts our usual modes of framing and discussion. Indeed, this discussion seeks to engage with the case study as Barry (2010) outlines and avoid the attendant danger case studies pose. Specifically, this chapter attempts to avoid the danger of 'becom[ing] and illustration of an idea . . . that has been formulated elsewhere', and to provide something '*more* than an example' (Barry, 2010; p.89). With this in mind, I turn now to consider asteroids and Outer Space as the 'new frontier'.

5.2 Outer Space as 'Frontier'

This section focuses upon how Outer Space is being framed as a 'final frontier'[95]. It begins by briefly mapping out what the complex term 'frontier' may be understood to mean and how the 'frontier' is simultaneously a site of opening and closing. The section subsequently moves on to consider how various actors are framing Outer Space as a 'frontier' and some of the implications this poses for the field. This section deals primarily with the 'opening' of the extraterrestrial 'frontier' as its enclosure is dealt with throughout Chapter 6 and contestations surrounding this term and the futures bound up within it are the preserve of Chapter 7.

5.2.1 (Re)Making the 'Final Frontier'

As previously noted in section 3.2.2, frontiers are often discussed in a normative sense: the (re)creation of frontiers being foundational to establishing new spatio-temporal fixes for capital, new resources, and attendant profits (Harvey, 1991: Jessop, 2006: Richardson and Weszkalnys, 2014). However, new frontiers do not simply appear of their own volition but are (re)created and maintained through a series of discursive practices that play out over and through both material and imaginative media. Furthermore, the domains wherein new frontiers may be formed are not limited to the material but are (re)created over and through imaginative frontiers also (Bridge, 2004: Li, 2014). This has been – and is – a key element in establishing asteroids as a new site for capital investment and subsequent extraction.

[95] Although this phrase is a popular tagline from the TV and film franchise *Star Trek*, it has been repeatedly used by NSE advocates, appearing in numerous media articles covering Outer Space developments, being used by numerous interviewees in the course of this research, and by multiple presenters at the conferences attended during participant observation. The abundance with which this phrase appears should put us in mind of Kirby's (2010) work on 'diegetic prototypes'. Indeed, the 'work' done by SF in creating and (re)shaping ideas of future technologies has been noted by Kaku (2011) in his book *Physics of the Future: How Science Will Shape Human Destiny and Our Daily Lives by 2100*.

As discussed in Chapters 2 and 3, Outer Space has often been referred to as the 'final frontier'; appearing in popular culture such as *Star Trek* and making a frequent appearance in asteroid mining company materials (see later discussion). Whilst this phraseology may be attributed to a socio-cultural imaginary grounded in a white, settler colonial positionality, it is also symptomatic of the extractive-capitalistic relations that are being created – and strengthened – to take place within Outer Space. The asteroid mining sector seeks to (re)imagine asteroids and Outer Space as the 'final frontier' via discourses disseminated through multiple media: discourses that draw upon settler colonial histories and perpetuate attendant normative imaginaries. Indeed, the use of settler colonial histories was made clear during several conference talks. The CEO of an NSE financial investment group told *SFF* attendees that "this is a crucial point in history: the most important in the past 300-400 years", referencing the 'Voyages of Discovery' and how the 'New World' was a site of profit-making potential[96]. Similarly, this point was made by the former CEO of DSI during the *ESPI* conference where they repeatedly referred to Outer Space as the 'new frontier' and drew upon historical examples of colonialism to illustrate their points: comparing ISRU to making use of materials in the 'New World to fuel expansion' and briefly discussed the similar opportunity for mineral 'bonanzas' when mining asteroids[97].

Moreover, asteroids and Outer Space are not only being (re)framed through multi-sited media, rather some are arguing that Outer Space represents a multiple frontier domain, each with its own promise, potential, and risk. *NewSpace Capital*, a private investment firm that focuses on NewSpace opportunities, neatly surmises this, stating that "Space is . . . a series of frontiers – from the Earth's orbit, to the Moon, asteroids and beyond. Each of these

[96] Taken from participant observation notes.
[97] Taken from participant observation notes.

frontiers is unique, and from the investment perspective has its own potential, horizon and risk-return profile"[98]. Whilst this sentiment (re)imagines Outer Space and asteroids as new multiple and variegated sites for capital investment and accumulation, various NewSpace actors are positioning the asteroid 'frontier' as a site upon which Outer Space futurity itself is contingent. Whilst the *Asteroid Mining Corporation* aims "to be pioneers settling new lands and forging new destinies for mankind in the final frontier" (mobilising the frontier discourse once more), they also position the asteroid 'frontier' as a site through which a multiplanetary future will be supported and encouraged, stating "we will build the infrastructure to support a space based [sic] population and in the process we will develop a space based [sic] economy, so that there is an economic incentive to live off Earth"[99]. So pervasive is this imaginary of Outer Space – or the disimagination process – that its positioning as a frontier is regarded by some as inevitable, a NewSpace consultant responding to my question on Outer Space and frontierism with a simple shrug and a single line: that "for better or worse, space is a frontier".

Given this seemingly 'inevitable' positioning of Outer Space as a 'final frontier' that perpetuates the expansionary logics of capitalism through providing a spatio-temporal fix for capital through (re)producing a site of capital investment and accumulation, the rest of this section occupies itself with the ways asteroids and Outer Space are being imaginatively engaged with. The second half of this chapter then turns its attention towards the material dimensions of asteroid mining before finishing with a section considering some of the theoretical implications this poses for the geographies of Outer Space.

[98] Taken from analysed web material: NewSpace Capital (2021), 'Investment Frontiers', available at https://www.newspace.capital/investment-frontiers/
[99] Taken from analysed web material: AMC (2019), ''About Us', available at https://asteroidminingcorporation.co.uk/about-us

5.2.2 Forging the 'Final Frontier'

Materials and our attendant relations with them are constituted through both the materials themselves and the socio-cultural practices surrounding them (Bakker and Bridge, 2006: Bridge, 2004b: 2009s: 2015). Just as this is the case for materials, so too is this true of frontiers (Li, 2014: Steinberg, 2018: Tsing, 2003). As discussed in Chapter 3, when certain resources become scarce, new ones come into existence through new and reconstituted relations to/with the materials in question (Richardson and Weszkalnys, 2014). These new relations with various materials leads to the redoubling of efforts to obtain key resources to maintain growth and, resultantly, new and hitherto unexplored 'frontiers' are recreated (Richardson and Weszkalnys, 2014: Tsing, 2003). This does not simply mean frontiers in the geographical sense, but these debates can open up new regulatory[100] and ethical frontiers also[101] (Steinberg, 2018). Additionally, the temporal can be construed as a site wherein new frontiers arise, being crucial in the constitution of speculation inherent within all frontiers. Given these points, asteroid mining fits neatly within these areas. It is spatial through proposing new spatial domains within which to operate and extract resources, temporal through (re)creating promissory futures, and continues to open up regulatory and ethical frontiers (see Chapter 3 for further discussion on 'frontiers').

Indeed, the culmination of these frontiers (the regulatory, the ethical, the spatial, and the temporal) and the materials with which they interact operate to (re)create frontiers as they are popularly conceived. The regulatory frontier is an area wherein issues of land tenure and ownership are thrashed out, taking on significance through its ability to greatly influence influxes of capital into mineral deposits (Bridge, 2004). This then operates as a regime of

[100] 'Regulatory frontier' are given further consideration in Chapter 6 in their relation to enclosing the cosmos.
[101] The idea of 'ethical frontiers' has been briefly discussed in the preceding section on terracentrism and the debates this concept opens up.

exclusion whereby (il)legitimate forms of use and abuse are differentiated and boundaries inscribed through physical or discursive means (Li, 2014). The closing of the frontier is achieved through enclosure (see Chapter 6).

Through these numerous openings and closings, actors not only seek to (re)create exclusionary boundaries, but to position the frontier as a site of 'bountiful emptiness' (Li, 2014). Co-opting the 'common heritage' principle[102] and positioning the frontier as a 'bountiful emptiness' may (and should) be read as a means whereby the frontier as a capitalist space seeks to replace various onto-epistemologies with capitalist expansion (Tsing, 2003). Through understanding this, we may look upon the opening and closing of the multitude of frontiers mentioned above and realise that new frontiers, in all their guises, seek to expand and (re)create possibilities for global capital (Valdivia, 2008). This point has been noted in the materialities literature by Bridge (2000) who noted that 'there is an inherent tension between the expansionary requirements of capitalist growth and the necessary increase in entropy (decline in free energy) that expansion involves, given the 'celestial constraints' of a closed system' (p.240). It is this tension that underpins the expansionary logics embedded in the development and perpetuation of the frontier noted by Tsing (2003). However, it should be noted that Bridge's point fails to note that the Earth is not a closed system as Newtonian physics had us believe. Instead, the Earth is open to all sorts of cosmic influences that impact and inform planetary geology and the forces thereof (Davis, 1997). This point becomes even clearer if one adopts a 'deeptime' perspective and accounts for the forces described in Clark's (2005) *Ex-orbitant Globality*. It is this expansion beyond the planetary boundary that asteroid

[102] See Chapters 3 and 6 for further discussion.

mining and its proponents are proposing. Private firms are seeking to 'open' Outer Space as a frontier, as DSI's website made abundantly clear when they wrote:

> ". . . Deep Space Industries is industrializing the frontier. Our mission is a daring one. We are journeying to unknown frontiers, and pushing the limits of technology to provide a brighter future for all of mankind."[103]

DSI's description of their 'mission' explicitly sets up Outer Space as a frontier, pointing to the processes with which they are engaged to 'open' this frontier. It places technology at the forefront of its operations to access and, consequently, enclose the frontier, industrialisation being given a key role here (see Chapter 6 for further discussion on legislation).[104]

However, the above quote not only indicates the way(s) private actors are seeking to open Outer Space as a frontier and promote interaction and initiatives within it. DSI's comment also provides an interesting point regarding the nature of frontiers. Although Li (2014), Steinberg (2018), and Tsing (2003) all make excellent points regarding the opening and closing of frontiers, they omit a key part of the frontier. Though noting that the materiality of the frontier is important (indeed, it is), this misses a crucial point – although the materials and resources of the frontier make it attractive, it is simultaneously a site of invisibility, as noted through DSI's reference to 'journeying to *unknown* frontiers'. The frontier, through

[103] Information retrieved from analysed website material (DSI (2017), 'Who we are' This webpage is no longer accessible).
[104] This enclosure is also being achieved through various forms of legislation in different nations around the world. Representatives from different NSE companies have bragged about their influence upon these policies (Participant Observation). The legislation and regulatory acts of enclosure are discussed further in Chapter 6.

being temporally and spatially distant, renders it not only a 'bountiful emptiness' (Li, 2014) but enables it to be engaged as a site of invisibility. This invisibility enables narratives to be created around materials known to be in these areas and also allows for various processes to be omitted (such as waste[105]). This invisibility fuels speculation through bringing what is known into conversation with that which is unknown. This idea of the frontier should be kept in mind as it will be returned to throughout what follows.

5.2.3 Projecting Dreams and Desires

As noted above, Outer Space's operating as a frontier offers a site of invisibility and, consequently, permits all manners of dreams and desires to be projected upon and within it. Through operating within the 'unknown'[106], actors with financial and political interests within the NSE create promissory futures regarding asteroid mining, projecting their dreams, desires, and fabulations into a seemingly 'void' frontier. Such machinations are part of a host of methods employed to garner traction for their plans, fuelling the public imaginary[107].

Considering this point, the ways in which the 'final frontier' comes to be understood subsequently informs the manners in which outer space and asteroids are related to. This ultimately influences the rationales that are formed to justify or refute attempts at enclosure and privatisation[108]. Furthermore, as noted in discussions on Ethnofuturism in the preceding Chapters, the cultural starting point adhered to is important throughout the processes of future-building and (re)creation: influencing how the frontier and materials therein are understood and related to (see Chapter 3 for further discussion). Thus, the socio-cultural -

[105] See Chapter 6 for further discussion.
[106] Relating back to DSI's quote in the previous subsection.
[107] This is discussed in Section 5.3.3 in regards to *The Next Giant Leap* exhibit and has been elaborated further in relation to the images in Figures 5.1 – 5.5.
[108] Discussed in greater detail throughout Chapters 6 and 7.

political informs relations and inclusionary/exclusionary practices; the frontier 'comes to be seen as a social construction as well as a material reality [that] carries cultural and political significance' (Redclift, 2006; pp.18). Thus, the asteroid frontier is as much a product of cultural imaginations as of geography and materiality; the notion of the frontier channelling into the imaginary, constructing images and relations that go beyond mere economic and physical processes, engendering new forms of cultural construction (ibid.). These cultural constructions of Outer Space influence the roles capital is conceived as playing in these scenarios and the material relations engendered therein[109].

Consequently, any site is regarded as a frontier operates as an area of projection for the hopes, dreams, and imaginaries of any group or individual. This subsequently operates to inform relations to, and understandings of, the extraterrestrial, enabled through the construction of the 'frontier' as a site of invisibility[110]. However, these are constructed through different imaginaries, alternative articulations, and counter-narratives that challenge and unsettle one another's constructions[111]. Indeed, this idea was discussed by Hannah Arendt in her work *The Human Condition*, as Kearnes and van Dooren note that "For Arendt . . . this space [Outer Space] was anything but empty morally and philosophically. Rather it is already fully laden with cosmic dreaming, theological wonderings, and science fiction fabulations" (2017; p.179). This is pertinent for the asteroid frontier: the imaginaries of various actors being projected here, culminating in a variety of futures and relations.

NSE actors have constructed the extraterrestrial frontier in numerous ways, throughout the material collected for this research. However, despite this variety, all the NSE

[109] Developed further in Chapter 6.
[110] Elaborated further in Chapter 6.
[111] These points of contention and alternative articulations are considered at length in Chapter 7.

actors and material engaged adheres to EuroAmerican-centric onto-epistemological framings of what the frontier is, what it may be, and how it can/should be engaged. Specifically, these imaginaries all constructed Outer Space, and the frontier thereof, as a site for perpetuating capital relations and accumulation. This accumulation has been advanced through projects seeking the extraction of new/more materials, producing 'services', and constructing new commodities, data services, and tourism opportunities. Each 'opportunity' depends upon the NSE sector being interviewed/researched[112]. Indeed, this framing of Outer Space was neatly surmised by Jerry, an NSE consultant, when he said: "The frontier hit the West coast and then it went up". Jerry's comment illustrates the way(s) in which the structuring of Outer Space as a frontier within the NSE community relies on understanding it through the same capitalist-colonial framing(s) as the 'frontier' of the Americas. This framing of understanding and constructing the frontier further emphasises the idea of the frontier as an empty space that may be projected upon in various ways. However, this point not only speaks to the framing of Outer Space as somewhere to be constructed and projected upon. The framing of Jerry's statement also implies what is being projected into space. The 'frontier [that] hit the West coast and then went up' is the same capitalist-colonial onto-epistemologies that informed the 16th century frontier and the capital relations and rationales imbued within those relations (McLeod, 2010: Redclift, 2006). These capitalistic relations subsequently inform, implicitly or explicitly, the socio-material relations with asteroids through framing NSE activities and extraterrestrial extractivism as spatio-temporal fixes for capital and entities from which profit may be derived (Harvey, 2008: Jessop, 2006). Jerry's point of the western colonial frontier hitting the West coast and travelling up speaks to the same underlying principles being used,

[112] Chapters 1, 2, and 3 discussed many of these projects and they are elaborated further later in this chapter.

though finding a new orientation – i.e. a frontier of verticality rather than the historical horizontal orientation[113]. Furthermore, the invocation of reorienting capital from a horizontal orientation to one of verticality also draws upon historical and contemporary issues of capital and the relations thereof coming to occupy strata, the deep sea, and air, instigating a politics of verticality[114]. This reorientation, therefore, provides a striking metaphor for the manner in which the capitalist-colonial project's logic continues to operate within a new domain, proceeding to inform and construct the understandings of, and relations to, Outer Space and the materialities therein (i.e. asteroids). Indeed, this structuring of Outer Space has been regarded as inevitable by some in the industry, as Giles, the VP Government Affairs of a private space firm, tells us: "For better or worse [space] is a frontier".

Giles' framing outer space in such a way is demonstrative of how many within the NSE conceive of Outer Space as being an irrefutable frontier. Construing Outer Space as an inevitable frontier means having all of the baggage bound up within this term applied to Outer Space. It projects a series of assumptions and capital relations upon Outer Space. Giles' comment alludes to the point that this frame of reference – Outer Space as a frontier – is now unquestionable or, at the very least, the dominant discourse has become so entrenched as to be unshakable. As noted, this is a point often made by actors within the NSE and is frequently relayed as an 'inevitability'[115]. However, this point is not accepted by all within the NSE community and is a massive point of contention with those 'outside' of the NSE domain[116].

[113] This point is discussed further later in the chapter.
[114] See Bridge, 2013, Childs, 2018, and Clark, 2017 for further discussions
[115] Not only have NSE actors such as Giles relayed this in interviews, multiple people have stated such a conviction throughout the participant observation undertaken as part of this research.
[116] This contention is picked up further in Chapter 7, discussing alternative futures posited by Ethnofuturists and even some reservations by NSE actors.

5.2.4 Socio-Political Materials and Extending Capital Accumulation

As noted at the outset of this section, the 'final frontier' and the materials therein (i.e. asteroids) are constituted through both the materials themselves and the socio-cultural practices surrounding them and their associated relations (Bakker and Bridge, 2006: Bridge, 2004b: 2009a: 2015: Li, 2014: Steinberg, 2018: Tsing, 2003). Much of these practices and relations are informed – implicitly and explicitly – by and through the socio-historical context(s) of 16th century mercantile capitalism and the capitalist-colonial logics this entailed[117].

The capital relations presupposed in these logics constructs and informs the way(s) in which asteroids are engaged with. The projection of logics that governed the Western frontier, colonial in their nature and the capital relations they then beget, therefore influence and inform the activities and relations that are imagined to (and do) take place within these areas and that come to be regarded as (in)appropriate. Thus, the (re)articulation of, and adherence to, Eurocentric frontierism as practiced during the post-16th century creation and expansion of capitalism (McLeod, 2010) informs a series of relations in which extractivism and capital accumulation are paramount. It is this formulation of the frontier that many of the NSE actors espoused[118]. Indeed, it is this extractivist and accumulatory logic that the asteroid mining project seeks to exploit and capitalise upon. We may regard the adherence to, and perpetuation of, this logic as existing in a dialectic relationship with the asteroid mining industry insofar as this capitalist logic provides the impetus/justification for such an endeavour, the industry then perpetuating this narrative and reinforcing it, thereby

[117] Indeed, during participant observation of the ESPI conference in September 2017 a presentation was given by the then CEO of DSI using the 'Western frontier' as an analogue for extraterrestrial expansion and a justification for asteroid mining.

[118] Chapters 6 and 7 discuss (de)regulation and voices of dissent/contestation over the extent to which this capitalist-colonial logic can/should be practiced.

strengthening this ontological position, which drives the industry further, and so on. This capitalist-colonial logic can be found in asteroid mining companies' advertising material on their websites through the activities they aim to engage in once they achieve access to the 'frontier' (discussed below). Through adopting the capitalist-colonial logic bound up in 'traditional' frontier narratives, asteroid mining ventures position Outer Space as a new spatio-temporal fix for capital and site for capital accumulation[119].

5.2.5 The 'Final Frontier': Inverting Verticality

As noted above, Outer Space relates to verticality *vis a vis* capital and its accumulation. Asteroid mining and the Outer Space 'frontier' may be construed as a series of spatio-temporal fixes for capital and sites from which profit may be derived and capital accumulated (Harvey, 2008: Jessop, 2006). This engagement with Outer Space requires a reorientation of our conception of a frontier as a site of horizontality to one of verticality.

This reorientation of the frontier from a site of horizontality to one of verticality is perhaps best expressed through Jerry's previous point that 'the frontier hit the West coast and went up'[120]. This point of the Western colonial frontier hitting the West coast and travelling up speaks to the same underlying principles being used, though finding a new orientation – i.e. a frontier of verticality rather than the historical horizontal orientation. Indeed, reorienting capital from a horizontal to a vertical orientation also relates to the historical and contemporary politics surrounding capital and depth, articulated through work on strata, the deep sea, and air[121]. This reorientation, therefore, demands a

[119] This framing of Outer Space is, of course, contested. Contrary views to that outlined above are discussed throughout Chapter 7.
[120] Comment made during interview.
[121] See Bridge, 2013, Childs, 2018, and Clark, 2017 for further discussions

(re)conceptualisation of capital and the politics of verticality. Construing Outer Space as a site of 'verticality' not only disrupts terracentric onto-epistemological engagements with mining, it also demands an engagement with the aforementioned 'projection' of socio-cultural histories and expectations upon and into Outer Space. Amongst these expectations is the assumed continuation of capital-colonial relations and the various logics this entails. Thus, building upon the inversion of verticality (discussed in subsection 5.4.3), Outer Space not only becomes a site of 'ultimate verticality' but also a site of 'ultimate depth'. This inversion of depth, alongside the adoption of capitalist-colonial histories and their associated logics, culminates in Outer Space becoming a frontier and site of capital accumulation[122]. Although the articulation of Outer Space is often framed as a new 'frontier' and, consequently, a site of capital accumulation, this point is not uncontested and is picked up further in Chapter 7.

5.2.6 Asteroids: From Existential Threat to Capitalistic Opportunity

Relations to both the imaginaries and practicalities of asteroid mining have shifted over the past half century. What started as a hypothetical debate in the 1970s/1980s (McCurdy, 2011) has gradually become an accepted idea within State-sanctioned missions through ISRU and, more recently, become accepted as a tangible 'reality' through various projects engaged with by private actors. However, shifting relations are not the sole preserve of expectations *vis a vis* the notion of asteroid mining. The prospect of asteroid mining has instigated a shifting of relations in numerous areas: most notably in how asteroids are moving from entities of planetary risk[123] to sites of capitalistic opportunity. This subsection will briefly

[122] We may think of Bridge's (2013) 'Territory: now in 3D' here.
[123] We may think back to the conversation in Chapter 2 here.

explore the shifting relations with asteroids and how they are being (re)imagined as sites of opportunity rather than existential risks.

The discourses of asteroids have shifted significantly over recent years following the founding of the first asteroid mining companies in two distinct ways. Firstly, alterations and (re)considerations of asteroids have shifted in their totalising discussions of asteroids, each asteroid now having a distinct 'identity' created around its attendant materiality. Specifically, this is derived from each asteroid having its own movement and gravitational mass. Although asteroids may be found in orbit around the sun (Erickson, 2019), each possesses its own axis and associated rotation, topography, and its size, density, and composition culminate in different gravitational masses. This poses a series of alterations in thinking about extraction in these environments that are not encountered on Earth (see section 5.4). Here, I focus solely upon asteroids' materiality and the shifting relation this causes. After considering this materiality, I briefly outline how asteroids are being reframed from a source of existential threat to a site of opportunity.

The principal shift in relations with asteroids regarding extractivism is the vastly different nature of the particulate matter being mined from them. When mining on Earth, extractive industries encounter particulate matter that has been subjected to tectonic, hydrological, and aeolian processes. The latter two of these processes weather particulate material so it becomes relatively rounded and smoothed, and tectonic processes can produce some igneous, sedimentary, and metamorphic rocks that are rather smooth also. These processes are absent in Outer Space, resulting in incredibly coarse, angular particulate matter. This may at first appear a trivial point until we consider the case of *Off World Research*, a company that has been working on creating lunar and asteroid regolith simulants. The

company began by taking various materials and mixing them to make approximations of the lunar and asteroid regoliths' composition. They proceeded to break these materials down and mix them more thoroughly through a series of mechanised processes. Eventually, the machinery began breaking down. It was assumed that this was a fault in the devices, so they were repaired, and the processes started again. Once more the machinery 'malfunctioned'. This series of events was repeated until the company realised that the machinery was breaking down as a result of their simulants. They had made a simulant that was nearly as coarse and angular as the regoliths they were trying to simulate and it was the angularity of the particulate matter that was tearing their equipment apart[124]. Through this realisation, *Off World Research*'s process of creating asteroid simulants and finding the adverse effects on their machinery were actually desirable forces us to (re)consider the processes and relations bound up within extraction and the implications this materiality bears for the asteroid mining project[125]. It forces questions around the viability of asteroid mining as it appears that mining materials from asteroids will tear through machinery fairly quickly, wearing it down much faster than terrestrial deposits would. It is one of a series of challenges the asteroid mining sector will have to overcome and has yet to answer.

The second shift in relations to asteroids comes not through their materiality *per se*, but through reconceiving them from a source of existential threat to a site of capitalistic opportunity. Asteroids have frequently appeared in the media and been represented as an existential threat due to their potential to create extinction-level events (we may think back to Chapter 2 here)[126]. This framing of asteroids as existential threats has led to some

[124] This information was relayed as part of Off World Research's presentation at the *Space Frontier Foundation*'s conference (Participant Observation).
[125] Considered further in section 5.4.
[126] For one of the most recent commentaries on this existential threat, see: Clark (2019).

attempting to raise awareness through events[127] and others to comment upon Earth's 'preparedness' for such an eventuality[128]. In answer to this threat, various proposals have been forwarded, the most notable of which is the NASA Asteroid Redirect Mission (ARM)[129]. As the name suggests, this project aims to increase preparedness for an asteroid impact event through working to redirect the trajectory of an approaching asteroid, thereby averting the collision. Whilst this has been the popular depiction of dealing with such an event – either within the associated media coverage or through pop culture depictions such as 1998's *Armageddon* – responses to this existential threat have been shifting as asteroid mining has become increasingly accepted as a tangible reality. This shifting relation with asteroids – from existential threat to a site of capitalistic opportunity – has arisen in part due to the material relations that have been (re)formed around asteroids. As asteroid mining has become increasingly accepted and the potential value of the materials upon them speculated upon and realised, various advocates have begun calling for a different mode of engaging a collision-course asteroid. Rather than simply redirecting an asteroid and averting disaster as NASA ARM proposes, asteroid mining advocates have begun to suggest that these same asteroids should be mined for their materials rather than simply redirected. As space mining advocates Matloff et al. argue in their book *Harvesting Space for a Greener Earth* ". . . if we have to move [asteroids], why not use them?" (2014; p.116). This sentiment represents a

[127] Aside from various work done by space advocacy groups such as the *Space Frontier Foundation* (participant observation), a group of scientist and astronauts founded *Asteroid Awareness Day* in 2014 to publicise the risk posed by asteroids. For more information, see: Sample, I. (2014), 'Asteroid strike warnings build towards campaigners' big day of rock', *The Guardian*, https://www.theguardian.com/science/2014/dec/03/asteroid-strike-warning-campaigners-day-of-rock-awareness-day [05.09.2019].

[128] For some coverage on this point, see: Yuhas, A. (2016), 'Earth woefully unprepared for surprise comet or asteroid, Nasa scientist warns', *The Guardian*, https://www.theguardian.com/science/2016/dec/13/space-asteroid-comet-nasa-rocket [05.09.2019].

[129] See Wilson (2018) for further information.

significant shift in relations to asteroids, having moved from conceiving them as sources of existential threat to sites of opportunity for private companies and, consequently, capitalism.

5.2.7 Opening the Frontier

This section has sought to highlight the manifold means whereby Outer Space is being (re)imagined as a 'frontier' that is being opened as a site of capital accumulation and extraction. Through being imagined as an open 'frontier', the NSE and asteroid mining firms are assisting in the perpetuation of the expansionary logics of capitalism and its being subtended through extractive industries. It has discussed how Outer Space is being framed and engaged as a frontier in numerous regards. However, whilst these discourses assist in the (re)imagining of Outer Space and asteroids as sites of capital investment and accumulation, this relationship is not contingent solely upon the imaginary dimensions of asteroid mining and Outer Space futurity. Equally important are the material dimensions of asteroid mining and the various relationships these materialities (re)create. It is these materialities that I now turn to consider.

5.3 Asteroid Relations and Materialities

This section outlines and explores the concept of asteroid mining and how this New Space industry is being framed and planned. It begins by detailing Near Earth Objects (NEOs) and their various compositions before subsequent discussions regarding the socio-political-material relations (re)shaping around these constituent parts. After dealing with these areas, the section then turns to focus on how asteroids - and the mining thereof – are being framed as 'way stations' or spatial extension resources that enable the 'final frontier' to be 'opened' for exploitation (an area related to section 5.2). Through exploring this area, the section

operates not only as an analysis of asteroid mining but contextualises conversations in subsequent sections.

5.3.1 NEOs and their composition

Asteroids are small, rocky objects that orbit the sun comprised of particulate matter that failed to be incorporated into planets during the formation of the solar system (Erickson, 2019). Due to their gravitational masses being far lesser than those of planets, asteroids lack a spherical structure, being angular and jagged in shape and range in size from hundreds of kilometres in diameter to being the size of a pebble (Erickson, 2019). It is the larger and more 'resource rich' of these that asteroid mining companies are seeking to exploit (both the 'resources' and reasons for exploitation are explored in later subsections). However, although the majority of asteroids within the solar system reside in the asteroid belt between the orbits of Mars and Jupiter, asteroid mining ventures are focusing their sights on Near Earth Objects (NEOs). The focus on NEOs at the expense of the denser asteroid belt stems from limitations posed by current technologies and financial outlay to embark upon such a mission, highlighting the spatio-temporal constraints of such missions at present. Indeed, a former asteroid mining-CEO commented at the *ESPI* conference in 2018 "Why would we go all the way out there [the asteroid belt] when we have asteroids in our own backyard?". Both the distance and the time required are too great an obstacle for mining the asteroid belt at present, forcing asteroid mining companies to focus their attention on NEOs.

To contextualise the difference in both spatial and temporal terms, an NEO is an object within 1.3 Astronomical Units (AUs) of Earth, which is ~120.9 million miles (CNEOS, 2019)[130]. The asteroid belt, however, is between 2.2 and 3.2 AUs from Earth (~204.6 – 654.72 million

[130] 1AU is equal to the mean distance between the Earth and the Sun over the course of a year.

miles) (Williams, 2016). The difference between the two means that conducting any mission to the asteroid belt would between 1.69 and 2.46 times greater in both distance and the time taken than that required for a mining mission at the upper limits of NEO distances. Although a distance of 1.3 AUs may still seem like a vast distance, it is close in the context of the solar system, Neptune being ~29AUs from Earth, for example (McClure, 2017). With their being relatively close in the context of the solar system and nearly half the distance away than the asteroid belt, NEOs are often cited as prime sites for extraterrestrial extraction as they "are easy to access as they travel around the Sun in very similar orbits to Earth. Additionally, these small bodies have very little mass, and therefore very little gravity, making it easy to extract resources"[131]. Indeed, 1.3 AUs is the upper threshold of an NEO, there being many asteroids that travel much closer to Earth, such as Ryugu that has been visited by JAXA at 187 miles from Earth (McCurry, 2019). However, although very close to Earth, upon completion the mission will have lasted six years (McCurry, 2019), highlighting once more the relatively long time horizons at play when engaging with, and theorising, asteroid mining. However, Ryugu was a scientific mission that required far more precision than plans for asteroid mining, wherein the whole asteroid is excavated rather than samples collected and returned to Earth. These time horizons have been downplayed by asteroid mining actors (such as the former-CEO noted above) who stress that these materials would be used for off-Earth purposes (such as those detailed in figure 5.1), reducing the time taken by these 'missions' and speeding up their 'return' on investments.

The supposed merits of asteroid mining have been touted by space enthusiasts and, increasingly, private companies for all manner of reasons. Such claims range from asteroid

[131] Information retrieved from analysed website material (DSI (2017), 'Asteroid Mining: An unlimited future for all mankind'. This webpage is no longer accessible.

mining's potential to create a 'trillion dollar' industry[132] to suggestions that it can save Earth from ecological destruction (see Matloff et al., 2014 for an overview). All these claims are premised upon the purported abundance of minerals contained within asteroids. Minerals most often cited in reports and discussions of asteroid mining include, but are not limited to: water; iron; nickel; and platinum group elements, as depicted in Figure 5.1. Alongside the seeming abundance of minerals, advocates of this nascent industry point to various comparative advantages, such as those listed in Figure 5.2. The infographic and marketing piece has been produced by *Brand Delta-V*, a marketing and advocacy group for the NewSpace sector. Rather than simply highlighting the minerals that may be extracted from asteroids, the infographic has sought to emphasise the relative merits of asteroids over the Moon (another site of contention in debates surrounding extraterrestrial extraction). Although the infographic makes mention of the 'rich range of resources' and that 'H_2O [is] readily extractable', the additional advantages of readily accessible orbits with near-Earth passes, low fuel and thrust requirements, and 'perpetual sunlight' are all areas asteroid mining companies and space exploration enthusiasts point to when attempting to advance their cause (though, given the claim of 'perpetual sunlight', one may wish to consider the fate of ESA's Philae lander, which found itself stuck in shade cast by parts of the asteroid's surface (Yuhas, 2014)).

[132] Point made during participant observation.

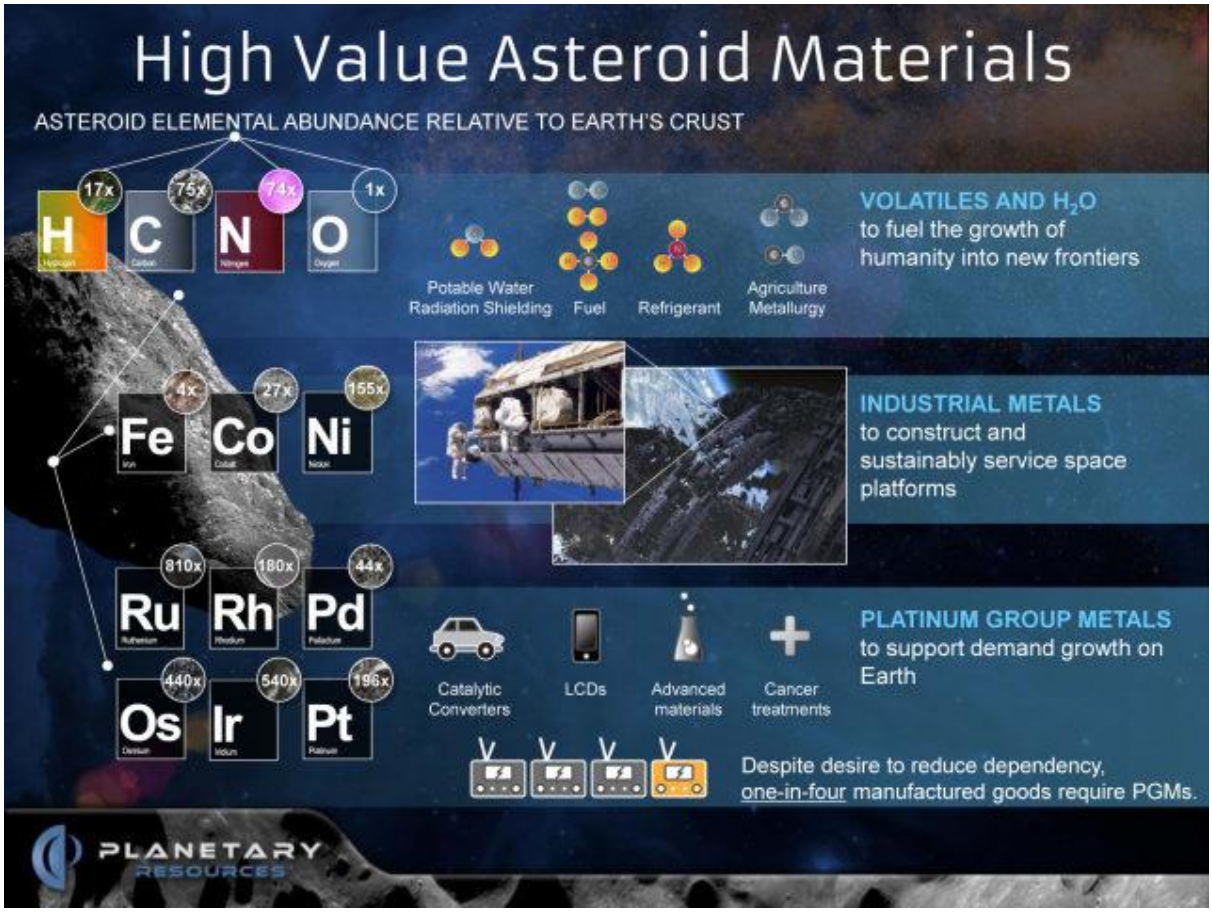

Figure 5.1: Planetary Resources Infographic via engineering.com, 2017 (source: https://www.engineering.com/DesignerEdge/DesignerEdgeArticles/ArticleID/15308/Asteroid-Mining-Who-Wants-to-be-a-Trillionaire.aspx)

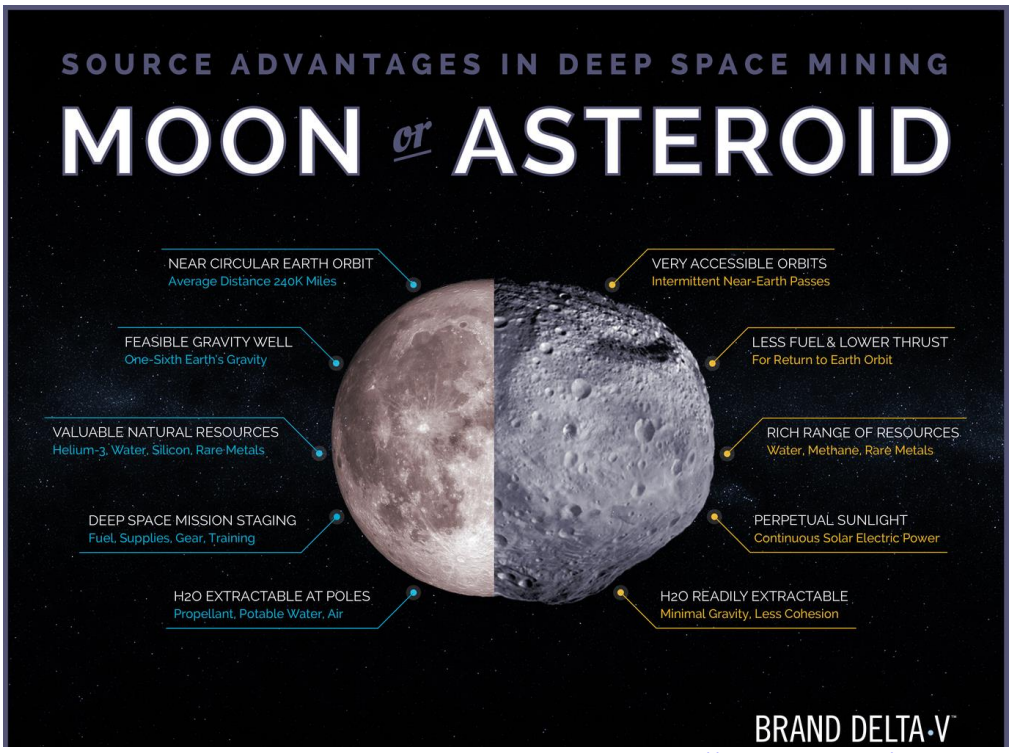

Figure 5.2: Brand Delta-V 'Moon or Asteroid' Infographic (source: [https://branddeltav.com/moon-asteroid-space-mining/)](https://branddeltav.com/moon-asteroid-space-mining/)

Although advocates of asteroid mining have sought to highlight advantages such as those in Figure 5.2 the principle driving force behind these ventures is the harvesting and selling of the 'resources' contained within asteroids. These resources and potential/intended uses are diverse and depend upon the narrative being created to justify any such endeavour. The resources and uses often cited include those depicted in the infographic in Figure 5.1. Broadly speaking, companies break down asteroids into four constituent groups. Firstly, 'volatiles' include elements such as Hydrogen, Carbon, Nitrogen, and Oxygen, their purpose being to 'fuel growth of humanity into new frontiers' (as discussed above). This idea of 'fuel[ling] growth' also implicitly refers to how asteroids may be used as spatial extension resources and can also be read as fuelling growth more broadly, potential markets around asteroid mining being advertised as being in the trillions: being briefly discussed in the *Space: A trillion dollar market* panel[133] and repeated through media coverage and popular YouTube videos (see Carter, 2020: EV Stock Channel, 2020: Farrell, 2013: Jamasmie, 2014: Rincon, 2013). Secondly, industrial metals include iron, cobalt, and nickel, the intention being to use/market them 'to construct and sustainably service space platforms'. Thirdly, there are platinum group elements such as ruthenium, rhodium, palladium, osmium, iridium, and platinum. Whereas the first two groupings are intended for use in Outer Space, the proposal for this grouping of elements is to bring them back to Earth 'to support demand growth on Earth'. The final section an asteroid's material body is broken down into during discussions is that of water. This section has a broad range of suggested uses and markets. Despite these groupings of materials frequently being discussed as though independent of one another, it is worth noting here that the small gravitational masses of asteroids results in there being

[133] Held at the *Space Frontier Foundation* conference 2018.

little or no stratification within their bodies, these elements being mixed together (hence the infographic in Figure 5.2 telling us asteroids have 'less cohesion' than the Moon). These groupings are given further consideration in subsequent sections[134].

5.3.2 Beginnings: Industrial Metals and Platinum Group Elements

Commercial ideas regarding asteroid mining have been voiced since the late 1970s/early 1980s (McCurdy, 2011) and have appeared in various SF movies and literature even earlier, as discussed in Chapter 2. However, these plans still seemed distant and intangible when they were first aired, remaining firmly rooted in the realm of science fiction. This changed drastically in 2012 following the announcement of the first two asteroid mining companies – DSI and Planetary Resources. This spurred on much discussion and speculation amongst space exploration advocates and commentators at the time, and both companies have sought to boost their profiles and galvanise interest in numerous ways. Both have been involved with the *Space Frontier Foundation* (a libertarian space advocacy group) to some degree and various members of their boards have mentioned being a part of lobbying movements that resulted in the SPACE Act 2015 being passed[135].

At their launches and subsequent press releases and media interactions, both DSI and Planetary Resources were keen to highlight the abundance of 'resources' that awaited extraction in Outer Space. Of the resource groupings outlined above, initial talks and coverage of these companies often foregrounded platinum group elements and industrial metals (see Rincon 2012 and 2013 for examples of this). The foregrounding of these minerals in early

[134] Although these groupings are considered later in the Chapter, volatiles are not considered further. This is due to the lack of discussion these have received in asteroid mining discussions. Indeed, they are seldom given any more consideration than that depicted in Figure 5.1, meaning that a subsection on volatiles would be short, brief, and devoid of the depth present when discussing the other three groups.

[135] Claims made by various NSE entrepreneurs at the NSE conferences attended. Claims have also been made to playing roles in shaping Luxembourg's space mining policy.

discussions was likely due to their being the most valuable/fiscally relatable within a terrestrial context, vast networks of investment, speculation, and markets already being well established to make sense of them. With their materiality and uses being readily comprehensible, platinum and industrial metals were the best positioned of the four material groupings to spur discussion, speculation, and fuel imaginaries relating to these projects, giving them more traction than placing volatiles or water at the vanguard of announcements.

Indeed, industrial metals are quickly and easily understood through their uses in building and construction, as is the monetary value of platinum metals, resulting in little work being required to 'translate' the worth of these materials. The ways in which these materials are readily understandable in a terrestrial context is made clear in Figure 5.1. Although most of the materials within asteroids are intended to operate as spatial extension resources, it is easiest to convey this idea through industrial metals, Figure 5.1 noting their ability to 'construct and sustainably service space platforms'. Given these metals' popularity in construction and their uses in satellites and spacecraft, it is easy to see how their uses in Outer Space could be quickly and readily relayed from the outset of these ventures. Through articulating these intentions, coupled with popular understandings of industrial metals, asteroid mining companies have been able to mobilise the uses (both real and imagined) of these metals to spur on speculation and imaginaries pertaining to their projects.

These companies (and space advocates more broadly) not only sought to garner interest and speculation through positioning these materials and their materialities as enabling exploration of Outer Space to be continued and extended. Rather than promoting their programmes through solely tapping into imaginaries surrounding the extraterrestrial, they have also incorporated debates of sustainability and Earth's future viability in attempts

to garner interest and support for their projects. This has been the case for both industrial and platinum metals, though with particular emphasis on the latter. Arguments range from extraterrestrial mining allowing polluting industries to be removed from Earth, thereby reducing the damage done by extractive industries, to being able to mine more minerals necessary to the manufacturing of 'green' technologies. These arguments have been present since asteroid mining's inception (see McCurdy, 2011 for an overview) and have been applied to both metal groups (see Matloff et al., 2014 for some discussion[136]).

However, although both industrial and platinum metals have been discussed in relation to a planetary future, platinum metals have received the most attention in this regard. The rationale for mining these has been linked most strongly to terrestrial imaginaries/operations than any of the other groupings. This is neatly surmised in Figure 5.1, where we are informed that platinum group elements can be mined for use in LCDs, catalytic converters, 'advanced materials', and cancer treatments. Indeed, there has been an increased demand for platinum group elements over the past 25 years and asteroid mining companies have been quick to adopt this increasing demand to justify aspects of their projects. Demand for platinum alone has increased nearly fourfold since 1988 and its use in catalytic converters and plans for increased battery manufacturing (due to electric vehicles) mean its use and consumption are set to continue increasing for the foreseeable future (LePan, 2019). Asteroid mining companies and advocates have adopted and mobilised these market demands and technological green futures into their discourses as one part of a multifaceted attempt to justify and fuel demand for their endeavours. Thus, far from simply arguing for asteroid

[136] Matloff et al.'s discussion focuses primarily on industrial metals. However, the book as a whole serves as an illustration of space advocacy's use of planetary future imaginaries, the book tapping into this through its title *Harvesting Space for a Greener Earth*.

mining as a new market that may allow capitalism to continue, asteroid mining advocacy has attempted to diversify its appeal through speaking towards (or co-opting) debates around climate change and the green movement.

The industrial and platinum metal groupings have done much to advance the case for asteroid mining over the years, appealing to sustainable construction of space stations, operating as spatial extension resources, satiating market demand for platinum uses in catalytic converters, medical uses, and batteries. This has been conducted not merely through an appeal to market demand (although this is a large part, given the private nature of these ventures), but has also sought to appeal to the green futures discourse, asteroid mining being positioned as a green alternative to terrestrial mining and industry. However, as noted at the beginning of this section, these groups were seized upon at the outset of these ventures for a number of reasons, not least of which was to galvanise intrigue. Although these metals are frequently discussed, they have been superseded by a much more valuable resource in Outer Space: water. Arguably, this has always been the primary focus of asteroid mining ventures, but the metal groups allowed quick, easy, and relatable discussion at the launch of these companies. In keeping with this turn to water, the importance and emphasis of this material is turned to in the next subsection.

5.3.3 The Emphasis on Water

As noted in the previous subsection, although asteroid mining companies began with launch events and material that highlighted the abundance and uses of various metals, the emphasis has gradually shifted to position water at the centre of these discussions. Plans to mine water from NEOs were present in initial discussions and coverage (see Rincon, 2012 and 2013 for examples). However, water was often overshadowed by discussions of industrial and

platinum metals, often given little more than a cursory mention. This was likely due to the metals having more tangible and readily relatable uses and market values than a seemingly mundane material such as water. Indeed, given the usual context of water, it is comparatively mundane in many terrestrial settings and has a fraction of the market value enjoyed by metals. Thus, it is easy to see why initial reports surrounding asteroid mining may have regarded water as comparatively trivial and often mentioned it in passing.

However, water has arguably become the most sought-after resource to be found on asteroids and has, over the course of the decade, become central to discussions pertaining to asteroid mining and asteroids' subsequent evaluations: its importance also being noted in fiction, such as major's *Trade Winds* where a character "had a list of minerals they wanted, and of course, water was the highest priority" (2011; p.187). Water has always had a key role within asteroid mining ventures and has gradually come to dominate discussions given its primacy in these debates. Having been present in discussions from the outset, the relative value of water was likely less relatable to the lay public and financial investors at that stage, hence the focus on industrial and platinum metals at the launch events. However, work has been done by companies such as DSI and Planetary Resources to relay the importance of water to these groups over the years through a variety of marketing material (discussed further later in this section). Not only have these companies worked to communicate the importance and value of water in their missions, an array of other Outer Space ventures have been announced over the years that have operated synergistically with asteroid mining, assisting in conveying water's importance. Such ventures include both State and non-State plans for interplanetary projects, such as NASA's plans for manned missions to Mars (Daines, 2017) and SpaceX and Mars One planning Martian 'colonies' (Mars One, 2019: SpaceX, 2021).

These projects, coupled with advertisements and public communications from asteroid mining companies, have operated to place water firmly at the centre of NSE debates.

Although the emphasis of these mining projects has shifted to the new material of water, the nature of the mining process itself has not shifted in any significant way. Searching for and mining water uses the same technologies and processes proposed for the extraction of metals in the same environments. This is due to the same technologies and processes being deployed to render these materials 'knowable' through their quantification[137]. Indeed, not only is the process of discovery and quantification the same as with metallic minerals, but so too are the methods of extraction being proposed. This similar means of extraction is due to the physical conditions within which water is to be found in Outer Space. Unlike on Earth, where water may be found in all three of its states, water exists solely as a solid on asteroids. This condition results in water being encountered as a mineral when being mined, culminating in its being extracted in the same manner as that proposed for metals (see the section on Terracentrism).

The centrality of water to asteroid mining is evident through resources produced by both DSI and Planetary Resources. As Planetary Resources' webpage in Figure 5.4 neatly informs us, water is most often framed as 'the key resource in space' when discussing any plans for sustained extraterrestrial activities, be that mining, space station habitation, or interplanetary missions. That water has been designated its own webpage within Planetary Resources' website is noteworthy, the space given to water alone highlighting the significance NSE actors are attaching to its extraction and procurement. The importance of water is stressed further within DSI's website, their webpage outlining asteroid mining and its

[137] Discussed above in 5.3.5

'promises' possessing an entire section on water also. Within this outline, DSI keenly stress the 'value' of water to extraplanetary futures and associated markets:

> "Water is the most abundant chemical compound in the Universe. It is abundant in our solar system and is fundamental to life and business operations in space. Water is vital to supporting human habitation for things such as drinking water, agriculture, radiation shielding, and oxygen.
>
> Additionally, water, as super-heated vapor, can be used as propellant. It can also be broken down into its constituent parts — liquid hydrogen and oxygen — to be used as fuel. Water is at the core of Deep Space Industries' work both today and in the future. It is the first resource we will harvest, and the first product we will sell. It is the basis for the propulsion systems that are being integrated into small satellites today, such as DSI's market-optimized Comet-1™ thruster. Water is the core resource that will support businesses and humans in space."[138]

The above information, taken from part of DSI's website, compounds the industry's rhetoric around the centrality of water's place in their plans. The above refers to water as being at the 'core' of industry operations. Furthermore, water's importance is stressed from the outset, DSI highlighting its use for survival and corporate operations, proceeding to outline numerous ways in which water may be utilised in an extraterrestrial context (this point is emphasised further in Planetary Resources' infographic in Figure 5.1). The above statement also indicates

[138] Information retrieved from analysed website material (DSI (2017), 'Asteroid Mining: An unlimited future for all mankind'. This webpage is no longer accessible).

water's capacity to operate as a spatial extension resource, being utilisable as both a propellant and a fuel. Perhaps the most interesting element within the above statement is the foregrounding of business operations, this phrase appearing alongside, or in front of, the survival of humanity in Outer Space. This may be read as a telling sign of private actors' relative valuation of continuing their operations. Through reading the above as such, we may then regard asteroid mining not only as a spatial extension resource, but as extending the lifespan of capitalism through the production and procurement of new materials and markets. The expansion of capitalism's lifespan in this instance is given equal footing, even primacy, over the survival of humans in space, the final line emphasising this point.

Moreover, during my time at the *Space Frontier Foundation*'s conference in Redmond, I visited the *Boeing Museum of Flight,* aware that *Boeing* has been involved in space programmes with NASA through its *United Launch Alliance* (*ULA*) partnership. I expected to simply go there and have a look around, assuming that, while they have been involved in space programmes, they would not have much particularly relevant to asteroid mining, this being the preserve of private companies like Planetary Resources and DSI. However, as I made my way through the museum and came to the section on space, I was surprised to find a large screen in the area with Planetary Resources' logo appearing on it. A short video entitled *The Next Giant Leap* began to play with concept art and accompanying captions, relaying the following:

> "Planetary Resources presents . . . The world's first commercial deep-space mission . . . A mission to find the most precious resource in space. . . Water. On

near-earth asteroids. To fuel human expansion" – *Next Giant Leap Exhibit*, Boeing Museum of Flight.[139]

This short film and the accompanying information operate to make the future of asteroid mining and its associated activities 'real' through the concept art and animations used, making the viability of asteroid mining more tangible[140]. Furthermore, this exhibit has been placed in an area where the public can access it, a public that is visiting a space museum and will, therefore, likely already have an interest in space and space travel, thereby garnering further support for the asteroid mining project. Alongside numerous online resources, this exhibit is but one of many ways companies have sought to bring conversations of water's importance out of the industrial sphere and into the public instead.

The emphasis on water here is pertinent. The exhibit does not make mention of industrial metals, volatiles, nor platinum group elements, but pays attention solely to water. This outreach and articulation highlight the primacy water has come to take in the asteroid mining sector, water having become the 'most precious resource in space'. What is more, the exhibit tells us that water, and indeed asteroid mining more generally, has a singular, sole purpose: "to fuel human expansion". Through framing water in this way, the exhibit stresses water's centrality to all extraterrestrial endeavours and aids in reinforcing water's primacy in related debates and discussions. Indeed, if we consider the "fuell[ing] human expansion" comment with DSI's above statement in mind, it comes to take on several meanings. The first interpretation is that water is a fundamental part of extraterrestrial ventures. The second

[139] Participant observation/fieldnotes.
[140] Section 5.3.5 discusses this in detail.

reading relates to the elements that water is comprised of: oxygen and hydrogen. Oxygen is intended as a component of life-support for space stations, whereas hydrogen is being framed as providing a fuel for spacecraft, thereby 'fuel[ling] human expansion' in a literal sense of the terminology[141]. The third interpretation of this statement, in light of the DSI's previous quote, draws us to questions of what aspects of the 'human' are proposed for expansion. Does this simply mean an increase in the physical distribution of human beings? I would suggest not, this conversation alluding instead to the distribution of humans and the associated systems they have created over the millennia. Specifically, this statement can be interpreted as the expansion of capitalism, its markets, areas of exploitation, and its regions of spatio-temporal fixes.

Thus, through the efforts of asteroid mining companies, the creation of synergistic Outer Space ventures, and the production and dissemination of information such as that discussed above, water has ascended from a seemingly marginal aspect of asteroid mining to become the primary material being searched for and (eventually) extracted. Water has been conveyed as the *most* important resource to be extracted from asteroids and is expected to be used with the other material groupings to operate as a spatial extension resource. I will now turn to discuss this spatial extension in greater detail.

5.3.4 Way Stations and Fuelling Sources

Throughout the brief history of the nascent asteroid mining sector, a core objective in the use of asteroids and their associated materials has remained consistent. Although we have seen how the industry's emphasis has shifted from glamorous metals to the seemingly

[141] Indeed, DSI have suggested using steam (water as H_2O) as a propellant in some instances, as noted in the company's above statement.

mundane (though massively important) water, all discussions related to these materials have sought to frame them through their ability to sustain and expand extraterrestrial projects. The articulation of asteroids as way stations or fuelling sources has remained consistent despite the shifting emphasis from one material grouping to another. Consequently, we may discuss asteroids *in totus* through this conceived utilisation.

Speculative discussions pertaining to the uses of asteroids as spatial extension resources in Outer Space were held in the 1970s and 1980s (see McCurdy, 2011 for an overview). However, these were regarded as solely hypothetical due to the 'reality' of asteroid mining being deemed an endeavour of the distant future. However, recent years have seen conversations of asteroids' (and broader extraplanetary) materials being used for such purposes moving from the hypothetical to the realistic. This shift has occurred through both State and non-State actors and their plans for extraterrestrial resources within their missions. A notable area of this shift from speculative to realistic is in the plans of NASA and ESA, both of whom have outlined plans for *In-Situ Resource Utilisation* (ISRU)[142,143]. As the name suggests, the purpose of ISRU is to take resources from an area of study or landing and use them towards the ends of a particular mission or to sustain a mission's lifespan. This is proposed not only to make missions more sustainable – thereby requiring less missions overall – but also serves to reduce the launch costs of missions through their requiring less materials from the outset.

[142] NASA's outlines for ISRU can be found at: Mahoney, E. (2019), 'In-Situ Resource Utilization', https://www.nasa.gov/isru [accessed 07.10.2019].
[143] ESA plans to use ISRU can be found at: ESA (2019), 'In-Situ Resource Utilisation (ISRU) Demonstration Mission', https://exploration.esa.int/web/moon/-/60127-in-situ-resource-utilisation-demonstration-mission [accessed 07.10.2019].

However, although the adoption of ISRU by State space agencies represents a large shift regarding the perceived viability of using extraplanetary materials as spatial extension resources, perhaps the most work done to shift public opinion and awareness around this has been done by asteroid mining companies. This is due to spatial extension being the core aspect of asteroid mining companies' commercial ends. Aside from State space agencies making spatial extension conceivable through ISRU, companies such as Planetary Resources and DSI have assisted in the shift from the aforementioned 1970s/1980s framing of such discussions as wholly speculative to 'realistic' due to their claiming to be operational in the near future (~10 years time[144]). These companies have not only assisted in making asteroid mining and associated ISRU more appealing through (relatively) short time-horizons, but have framed all materials as spatial extension resources since their foundings. This framing has remained consistent throughout the shifting focus from industrial and platinum group elements to water, highlighted in Planetary Resources' infographic in Figure 5.1. It informs us that industrial metals can be used to "construct and sustainably service space platforms" and volatiles and water can be used "to fuel the growth of humanity into new frontiers". This framing of asteroids and their ability to function as way stations and fuelling sources is emphasised further when brought into conversation with some of the comments made in previous sections, such as *The Next Giant Leap* exhibit and DSI's framing of water, or the intended uses for metallic groupings. Through framing asteroids and their associated materials in such a way, asteroid mining companies set asteroids up as spatial extension resources. Consequently, asteroids and their attendant materials become the gateways to sustained multiplanetary travel and extraterrestrial operations.

[144] Comments made during both ESPI and *Space Frontier Foundation* conferences (participant observation).

Although asteroids have been framed as spatial extension resources due to their associated materialities, as evidenced above, we may go further in our reading here. Discussions of asteroid mining and the uses of the materials that comprise them frequently position them as spatial extension resources, as outlined above. However, these materials and the uses conceived for them should be understood as facilitating an extension beyond that of mere spatiality. With the previous subsections in mind, the private nature of asteroid mining companies, and the various allusions to, or outright discussions of, business operations made by these companies, an ulterior extension can be proposed in addition to the spatial extension discussed thus far. Given the venues within which asteroid mining is being increasingly discussed, the nature of the companies proposing these operations, and those interested in funding such projects, I would suggest that asteroid mining represents a spatio-temporal extension resource for capitalism.

Asteroid mining comes to operate as such through its operating as a spatio-temporal fix for capital, its unlocking a new set of areas within which capital may flow (both spatially and through the creation of a series of new/diversified sectors), and through its developing a new series of complex financial networks within and through which capital may flow. Asteroid mining is spatial in its unlocking of new areas of extraction, capital investment, and operation. It is temporal in how it is operating to extend the life of capitalism through creating speculation, the 'opening' of new resource pools, and creating futures upon which investors may bet. Thus, asteroid mining culminates in a spatio-temporal extension resource that operates not only within the logics of capitalism but on behalf of it also. Through understanding asteroid mining as such, we can begin to discuss Outer Space as a frontier[145].

[145] See in section 5.2.

5.3.5 Making Asteroids 'Knowable'

The conversation thus far has outlined what NEOs are, why they are targeted by asteroid mining companies, and what they are comprised of. With these deliberations in mind, it is worth turning to consider how asteroids are rendered 'knowable' – i.e. how do companies locate or speculate about these resources and how do they fuel imaginaries pertaining to these materials and the ensuing socio-political debates that surround them? In answer to this, it is possible to locate three main ways in which asteroids and their attendant materialities are rendered 'knowable'. Firstly, the physical body of asteroids are analysed and explored. Both scientific missions and asteroid mining companies have sought to collect various data on the composition of asteroids, employing an array of methods to 'prospect' for minerals and elements. Secondly, after having made the physical materiality 'knowable', methods are employed to translate this information through concept art, fuelling imaginaries. Thirdly, having made the asteroid 'knowable' through both its physical properties and the imaginaries informed though this, the asteroid is subsequently financialised. Asteroids thus become 'knowable' through a combined effort of prospecting, concept art/narrative creation, and financialisation. I will now briefly consider each of these three points in turn.

As noted, the first method utilised to make asteroids 'knowable' is that of prospecting. Although various data have been collected through scientific missions, the commercial aspect of these findings has been a spin-off of original intentions, meaning that these processes are not prospecting *per se*. However, the methods incorporated into such missions are similar to those being proposed by private space ventures and their data have been used by those with commercial interests when making their cases, so can be included in this discussion. Prospecting, simply put, is the search for mineral deposits. The mineral searched for depends

on the objectives of the interested party and what is deemed valuable or desirable depending upon what it may be used for given the context or through its market value. As mentioned in the preceding section, there are four groupings of materials companies involved in asteroid mining are interested in, all of which appear as mineral (i.e. solid) deposits given the conditions within which asteroids are found. Thus, prospecting is the most apt terminology to apply to this aspect of asteroids' 'knowability'. The chemical/mineralogical composition of asteroids are obtained through both visual and sensory methods.

To achieve this information, both DSI and Planetary Resources have proposed and designed spacecraft specialised for prospecting asteroids. The resultant data operates to make the prospected asteroids 'knowable' through the quantified data retrieved from these prospecting missions. These data provide information regarding the abundance of various minerals on each asteroid surveyed, allowing asteroids to be ranked in order of 'desirability'. To this end, DSI have been developing the *Prospector-1*, a spacecraft designed to prospect NEOs and retrieve data regarding their composition. The *Prospector-1* uses a combination of visual data and infrared imagery to map the overall water content and minerology of the targeted NEO[146]. Similarly, Planetary Resources have been working on the *Arkyd-6* towards similar purposes. The craft uses a broadband imager that scans between 3 and 5 microns within the infrared region of the electromagnetic spectrum. This area of the electromagnetic spectrum is used due to its sensitivity to water – including water present in hydrated minerals – and to thermal energy[147]. Using this information, the craft is able to prospect NEOs for water content and, through this data, each asteroid's desirability can be calculated through its

[146] Information retrieved from analysed website material (DSI (2017), 'Prospector-1: Searching for valuable Searching for valuable resources on a near-Earth resources on a near-Earth asteroid'. This webpage is no longer accessible.
[147] Information retrieved from analysed website material (Planetary Resources (2017), 'About Arkyd-6', https://www.planetaryresources.com/missions/arkyd-6/ [retrieved 02.12.2017])

quantification, as illustrated in Figure 5.4. The data retrieved by these prospecting craft can then be used to infer certain properties and speculate about the monetary value of each asteroid. Indeed, Messeri (2016) notes how data can be used to 'place' Outer Space, "transforming numerical data from telescopes and satellites into full-blown worlds" that become "real only insofar as their visualizations [sic] are believable" (pp.2-9). We may regard the collection and compilation of mineralogical data about asteroids in a similar light. Data is taken and the graphs and charts subsequently produced are then used to make the asteroid 'knowable'. Valuations are then created based upon this data, as depicted in Figure 5.3 (explored further when discussing financialisation). These methods of prospecting culminate in the physical characteristics of asteroids becoming 'knowable' and this information is then used to galvanise interest through the proceeding activities of concept art and financialisation.

The second method employed to make asteroids 'knowable' is the production of concept art and the narratives associated with these images. The data produced through the quantification of the asteroid is used to produce various tables and graphs that inform us about each asteroid in question. These data are then used by some to create infographics and concept art that operate to encourage and stimulate discussion and speculation surrounding the asteroid mining project. Indeed, the rearticulation of data to produce concept art and lend credence to Outer Space projects has a long history, from creating landscapes for science fiction to playing a fundamental role in European 'astroculture' and NASA missions (Diaz, 2018: Dick, 2018: Ellis, 2017: Eisfeld, 2018: Garrett, 2016: Geppert, 2018: Messeri, 2016: Scoles, 2016: Triscott, 2016). This is similarly the case in the asteroid mining sector. If we consider the image in Figure 5.4, taken from Planetary Resources' website, this point becomes abundantly clear. The image depicts how the quantitative data collected from asteroids could

be used to appraise and relate an asteroid's value in relation to the abundance of a given mineral, in this instance water. Through producing this image, the asteroids depicted can be ranked in order of which will yield the most water upon mining. This image makes the information easily readable and understandable; the simplicity of the image renders the idea of asteroid mining much more achievable and tangible than a series of abstract graphs and electromagnetic spectroscopy diagrams may otherwise achieve.

Concept art does not simply take quantitative data and make it relatable, it is also used for the very idea of asteroid mining to become 'real' and 'tangible' through its depiction. Frequently, reports and online discussion forums discussing asteroid mining will be accompanied with concept art depicting mining in practice, such as those collected in Figure 5.5. Through their fuelling imaginaries and discussions around asteroid mining, images such as these can be regarded as what Kirby (2010) refers to as 'diegetic prototypes'. Although fictitious in nature, diegetic prototypes operate to stimulate imaginaries that subsequently inform discussion and debate. Through this process, the imaginative can be rendered 'real' and shape debates, policy, and public opinion. Through this process of making asteroids and their mining 'knowable', concept art and the imaginaries they help create can shape and inform the socio-political conditions that structure the socio-political-material relations surrounding asteroids. Although images such as those collected in Figure 5.5 make asteroid mining more 'tangible', it is important to note that they also render some issues invisible due to their intended purpose of making these projects desirable to some degree. All of the images relay asteroid mining as a process whereby the whole asteroid is ground up/mined for its minerals (due to the aforementioned lack of stratification due to small gravitational mass) and all omit depicting any form of waste product involved in the process (discussed further in Chapter 6). Thus, it is important to note in considering these images as 'diegetic prototypes'

that they encourage interest just as much through omission and invisibility as they do through rendering the speculative 'tangible'.

Akin to terrestrial mining processes, the third means by which asteroids are made 'knowable' are through processes of financialisation (Gilbert, 2017: Haywood et al., 2014: Reyes, 2016). Although prospecting and concept art result in asteroids becoming knowable and relatable, it is this third process that operates to garner investment and interest from NSE companies. This interest and investment culminate in (re)shaping the socio-political landscape surrounding asteroid mining, associated policies, and the socio-political-material relations all of this is bound up in[148]. Using the quantitative data gathered during prospecting, along with the imagined uses and demands of these materials, various valuations are placed upon asteroids and the materials within them. As previously noted, this method has led some commentators to speculate that asteroid mining is a potential 'trillion dollar industry', with an *SFF* panel discussion and numerous online sources framing asteroids as such (see Carter, 2020: EV Stock Channel, 2020: Farrell, 2013: Jamasmie, 2014: Rincon, 2013)[149]. These valuations are then mobilised to garner further interest in the potential of asteroid mining through the production of infographics, such as that in Figure 5.3. Such financial infographics enable the quantitative data gathered about asteroids to be translated into a fiscal lexicon, enabling speculation to occur and investments calculated. Not only does the financialisation of such data enable speculation to occur, but it also does similar work to concept art through its making asteroid mining intelligible to markets. Similar to terrestrial mining practices, this fiscal 'knowability' enables financial actors to then use this information in their economic

[148] Policy and its (re)shaping is explored further in Chapter 6.
[149] See Chapter 6 for further discussion on the speculative valuation of asteroids.

calculi, fuelling investment through a ‘knowability’ that is actually grounded in speculation (Gilbert, 2017: 2020a: 2020b).

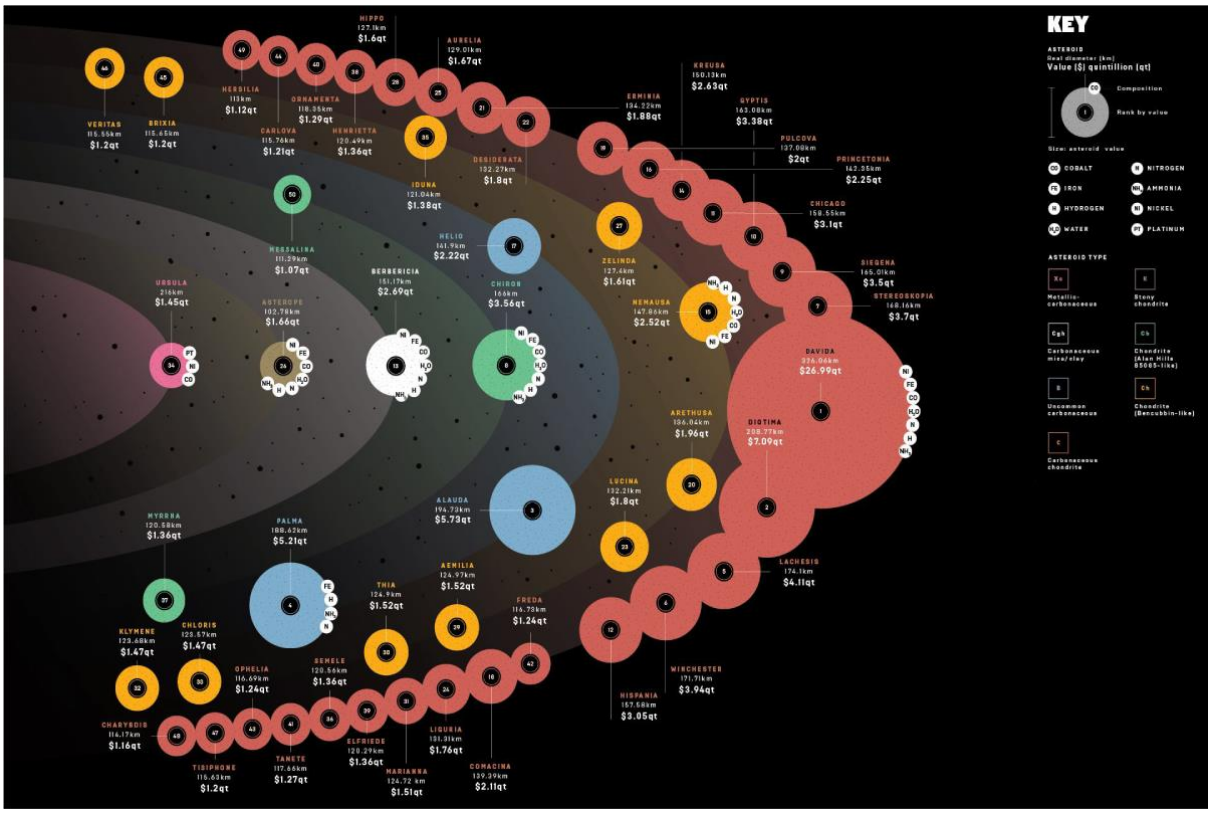

Figure 5.3: Infographic detailing some asteroids type, chemical compositions, and estimated values (sourced from: https://www.visualcapitalist.com/theres-big-money-made-asteroid-mining/)

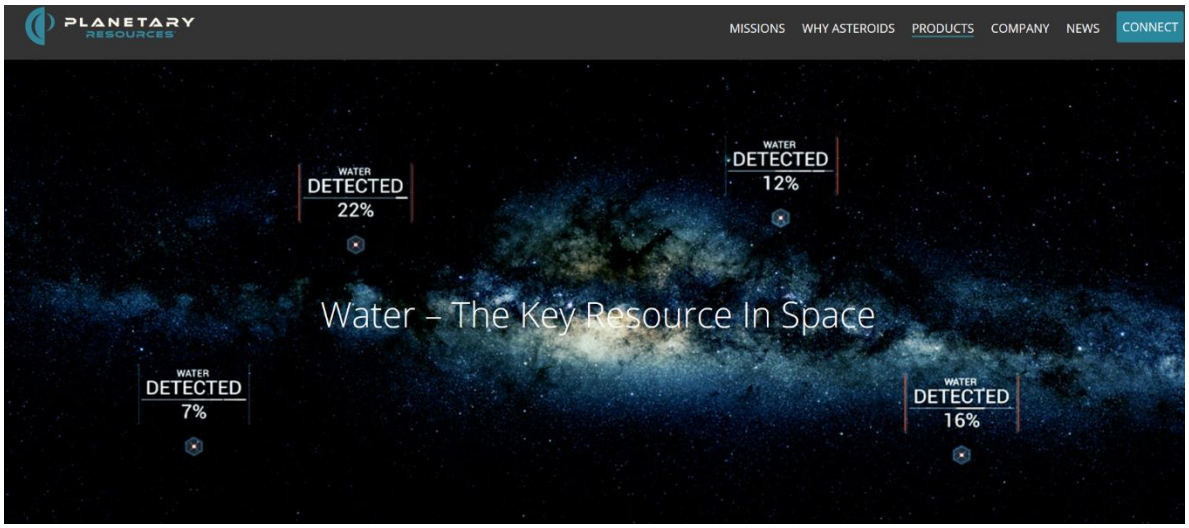

Figure 5.4: Planetary Resources’ Title Page on ‘Water – The Key Resource In Space’ (source: https://www.planetaryresources.com/products/)

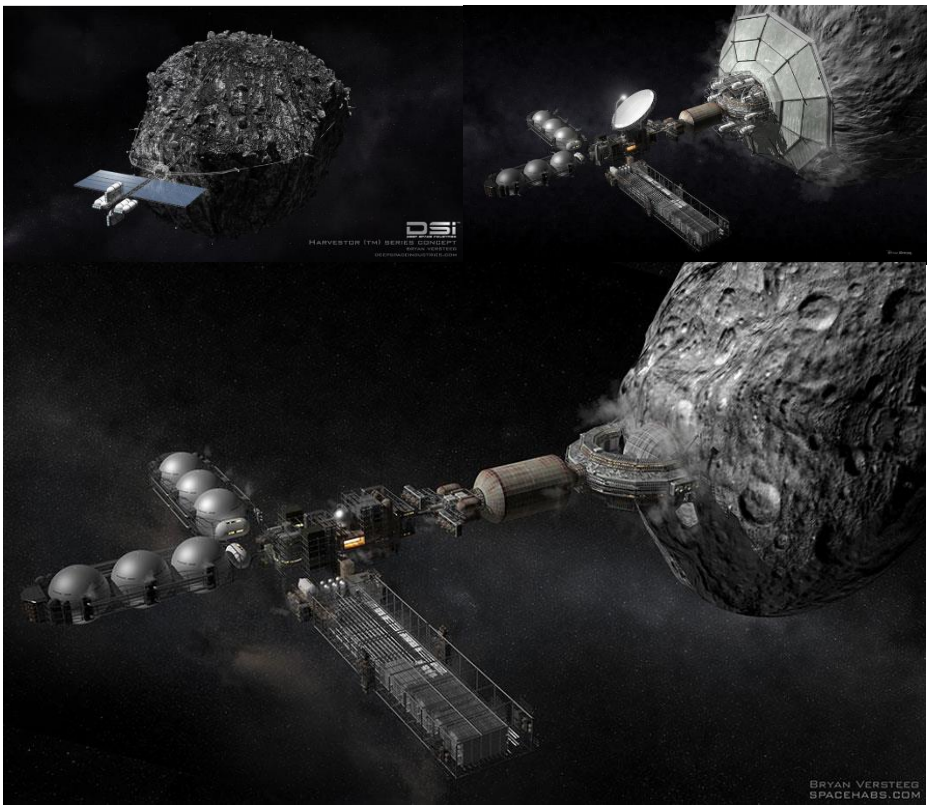

Figure 5.5: Top left: Concept art of DSI's Harvester Series (sourced from: https://www.digitaltrends.com/cool-tech/beginners-guide-to-asteroid-mining/)

Top right: Concept art of Asteroid Mining Apparatus by Bryan Versteeg (Sourced from: https://fineartamerica.com/featured/asteroid-mining-and-processing-bryan-versteeg.html)

Bottom: Concept art of a space 'smelter' by Bryan Versteeg (sourced from: https://space.nss.org/nss-roadmap-to-space-settlement-3rd-edition-2018-part-5/)

These three methods – prospecting, concept art, and financialisation – do not work independently of one another, but often inform or work with one another to (re)shape discussions of asteroids, their materiality, and the socio-political contexts these then come into conversation with. Furthermore, although these methods are employed in attempts to make asteroids and their constituent parts 'knowable', there is still much we do not know about asteroids. With this in mind, we should note that the financialisation of asteroids, the concept art created relating to them, and, to a degree, the quantified information pertaining to them are all speculative. Thus, when combined, some discussions and their underlying

assumptions are speculations based upon speculations. Only time will tell how accurate these predictions and conversations have been.

5.4 Terracentrism and (Extra)Planetary Forces

This section delves deeper into the ways asteroid mining troubles *a priori* concepts frequently used in geography and attendant debates surrounding extraction industries. It explores how debates and analyses adopt and employ an onto-epistemological lexicon constrained through its having developed in a solely *terrestrial context*. Through engaging with asteroid mining – indeed, any extraplanetary study – the limitations of simply applying analyses of terrestrial extractivism to an extraplanetary context become apparent. This section has a particularly conceptual inflection as it outlines the limitations of existing literature and proceeds to suggest how the Social Studies of Outer Space need to account for extraplanetary forces that differ vastly throughout the solar system. The section finishes by considering how this matters, using information on some landers, asteroids, and planets to illustrate the point by way of 'data'.

5.4.1 Beyond Terrestrial Critiques?

Mining has a long history in the terrestrial context, having spurred much commentary and analysis over the centuries (for example, Agricola, 1556 [1950]: Braudel, 1982: Bridge, 2000: 2004: 2013: Healy, 1978: Lynch, 2002: Mumford, 1934: Nef, 1964). These works have outlined the relations between labour, the economy, technology, capital, and modes of governance and power throughout mining's history, achieving much in the development and analysis of the socio-political-material relations bound up in, and (re)created by, mining. The history of extraction has seen the evolution of mining, the materials it has brought forth, and the technologies these have helped create culminate in an era wherein the properties of such

materials have enabled other technologies and, furthermore, people to break past the confines of Earth and venture into Outer Space[150]. However, although these works are doubtlessly useful and instructive in assisting discussions pertaining to asteroid mining, they are all constrained through their focusing upon *terrestrial* extractivism. It is obvious as to why this is the case – asteroid mining was not even conceived of, never mind a potential reality, at the time many of these works were written. Thus, through asteroid mining's being used as a case study we may meet Barry's (2010) requirement that it tells us something *new*. Specifically, asteroid mining draws our attention and discussions into a starkly different context; that of extraterrestrial mining. This context – Outer Space – necessarily challenges and disrupts much of our presuppositions surrounding extractivism through a host of new forces requiring thought and theorisation[151].

Indeed, although the literature surrounding extractive industries has been useful and instructive in our thinking through some of the issues pertaining to asteroid mining, the extent of its applicability in the context of Outer Space must be queried. The limitations of these discussions result from their focus on terrestrial mining and through recognising the variegated environments present throughout the solar system. With these points in mind, asteroid mining and the data at hand forces us to think through a series of issues that are absent upon Earth. Just as Dalby (2007) has noted the difficulty of thinking beyond 'terrestrocentrism' in discussions surrounding seafloor mining, there are also significant challenges in thinking beyond terracentrism. Terrestrial mining (including that of the seafloor) necessarily adopts a terracentric disposition to its operations. It has no recourse not to due to its operating within the confines of the Earth, though undoubtedly encountering manifold

[150] We may think of Barry's (2010) unanticipated actions here.
[151] See section 5.4.2 for further discussion on these forces.

complications throughout these processes. This terracentricity inevitably leads geographers (indeed, nearly all disciplines) to adopt onto-epistemologies that are conceived and constructed through and with understandings of materials and their materiality as they manifest *on Earth*. These terracentric onto-epistemologies take for granted numerous properties unique to Earth, all of which differ throughout the solar system and, consequently, no two sites or systems are the same as differences in each of these properties come to inform and shape vastly different (extra)planetary systems[152]. Thus, through appreciating these myriad forces and the manifold complexities they create and inform, our conceptual and empirical understandings of extraction are inevitably disrupted, requiring us to move beyond terracentric onto-epistemological framings to a mode of analysis that accounts for these forces in its critiques. Indeed, far from simply appreciating the socio-political-material relations the interaction of the material and social can inform (Bakker and Bridge, 2006) or the material imaginaries these create (Bakker and Bridge, 2006: Bridge, 2004b: 2015), acknowledging the terracentric dispositions we adopt demands a recognition that conventional work on extraction fails to account for many of the (extra)planetary relations inherent within extraterrestrial extractivism. Rather, we must move beyond considerations of terrestrial relations and towards a more dynamic understanding in which the social, material, and (extra)planetary forces are viewed as systemic and co-constitutive of one another.

5.4.2 New Forces to Consider

Although the social, material, and (extra)planetary should be regarded as co-constitutive of one another, a recognition of terracentrism poses a series of provocations.

[152] See section 5.4.2 for more detail on these conditions.

Realising our terracentrism and the Earth-bound relations this presupposes requires that we begin by considering the (extra)planetary forces and context wherein, and whereby, NSE activities are set to take place. These (extra)planetary forces include, but are not limited to, gravitational force, mass, atmospheric pressure and density, surface temperatures, whether or not there is a magnetosphere, distance from the sun, axial tilt, and the planet or planetoid's geology. Such (extra)planetary forces should be considered when discussing extraterrestrial extractivism. These forces are important in the terrestrial context but become of yet greater import when we move to Outer Space.

Indeed, if we consider the comments made by *Off Planet Research* regarding the effects lunar and asteroid regolith simulants had on the machinery they were testing, the importance of these extraplanetary forces and the disruption they create in the context of asteroid mining become particularly salient. The simulants created tore apart, destroyed, or quickly wore down much of the equipment they were using and testing. Realising that it was the damage done by the regolith simulants rather than the machinery malfunctioning was deemed a 'success'. This is because the coarseness and angularity achieved within the simulants were sufficiently mimicking that of extraplanetary regolith. The vastly different extraplanetary forces that surround the formation and constitution of these extraterrestrial minerals results in their becoming radically different to their terrestrial counterparts. This is due to the absence of tectonic, aeolian and hydrological forces operating on asteroidal particulate matter that operate to smoothen similar deposits on Earth. The absence of these forces results in the materiality one would expect in a terrestrial context being rendered void, particulate matter becoming instead something that requires much more work and wears out machinery more readily. It is only through foregrounding the extraplanetary that this observation becomes intelligible and stresses the importance of moving beyond terracentric

onto-epistemological framings of Outer Space and the various materialities woven throughout it.

5.4.3 Inverting Verticality

Further to the disrupting of terracentric onto-epistemological engagements with mining, asteroid mining and the research conducted around this leads me to posit that engaging this practice in Outer Space represents an inversion of verticality as it is conceived of on Earth. That is, terracentric modes of mining have engaged with verticality and depth through mining *down* to extract materials and bring the various ores and materials *up* (though we should also keep in mind that these processes also involve horizontality, moving sideways or along veins of various gradients). However, mining in Outer Space inverts this *a priori* logic through (from a terrestrial view) its moving through verticality by going *up* to subsequently bring materials *down*. With this realisation in mind, we must consequently begin to think of mining 'up' rather than mining 'down'. Rather than sinking shafts and overcoming issues of tunnel collapse, asteroid mining requires that gravity be overcome through escaping the 'gravity well' of Earth. It necessitates thinking upwards, rather than down. Of how the explosives used in the extraction of terrestrial minerals and rock have been harnessed to fire things off the Earth, rather than simply blowing it apart. How the technologies of mining have not only been used to build vertically (see Brechin, 1999 for an in-depth discussion on this) but to take people, industry, telecommunications, and more off Earth and into Outer Space. This point regarding the inversion of verticality does not stand on its own but should be brought into conversation with the previous point on terracentrism due to its disrupting those conceptualisations of mining. However, although it should be brought into conversation with the previous observation, it should be regarded as a point in itself as this conversation on

verticality can be engaged separately to that of terracentrism, with its wider focus on (extra)planetary forces. Furthermore, through seeking to take mining into outer space, not only is the operation of mining and its relation to verticality thrown into question, but so too is the relation to the struggles surrounding issues of gravity. We may regard terrestrial mining as having been fraught with issues of overcoming conundrums posed by gravity, whether this be through having to deal with landslides/cave ins, having to prop shafts open through reinforcement, or hauling excavated material out of the mines through winches[153]. This set of issues also comes to be inverted as, through moving outside of a terrestrial locale, gravity poses the opposite problem. Rather than trying to resist gravity's making things come closer together (as in tunnel collapse, for example), in an extraterrestrial context the challenge becomes how to keep materials or the target for mining together, the force being considerably weaker than that found on Earth. Consequently, Outer Space inverts issues and deliberations regarding both verticality/depth and gravity.

This consideration of the inversion of verticality in mining can be extended further through construing extraterrestrial mining as representing an 'ultimate verticality'. I suggest this as plans regarding asteroid mining not only disrupt or move beyond terracentrism, nor do they simply invert the *a priori* logics applied to mining, but represent an almost unbounded verticality should it be realised and become fully operational. Of course, a caveat to this point should be that it only represents an unbounded verticality from a terrestrial viewpoint[154] as, once outside of Earth's boundaries there is no longer an 'up' or a 'down'. As noted in Orson Scott Card's *Ender's Game,* breaking away from Earth results in a disorientation of verticality

[153] Some fantastic illustrations of these latter two can be found in Agricola's (1556) [1950] *De Re Metallica* (specifically book 6).
[154] Ergo, terracentric in itself perhaps.

as there is no 'up' in space and, consequently, attempts at conceptualising verticality without a reference point become nigh on impossible. However, with considering verticality as it is popularly conceived on Earth, this point stands. Through conceiving of Outer Space as an 'ultimate verticality' we may begin to conceptualise it as an almost unbounded realm. With this thinking in mind, various actors have argued that Outer Space represents an infinite 'frontier' full of bountiful resources (as discussed throughout section 5.2).

5.4.4 What Does This Mean?

Recognising and accounting for the disruption posed by an extraplanetary domain and the forces therein during our discussions of asteroid mining means we can begin to overcome the shortcomings posed by simply applying terrestrial mining analyses to Outer Space: a set of issues noted by Fickling (2020) in their overview of popular asteroid mining discussions. Recognising and appreciating these forces enables us to begin thinking of the vast complexity posed by asteroid mining and how the shifting contexts imposed by extraplanetary forces throughout the solar system results in shifting materialities and material relations depending upon where (and when) activities are undertaken.

For example, consider Japan's Hyabusa2 lander that weighs ~1.1Kg (JAXA, 2018). If we assume it to be hovering at 2 meters, a terrestrial reading of its gravitational force would suggest that this is around 1.10×10^{14} newtons. However, if we were to take Hyabusa2 and place it in the context of the asteroid Ceres, then its gravitational force becomes 1.72×10^{10} newtons[155,156]. Hyabusa2's properties have thus changed not due to its materiality *per se* but, instead, it is the (extra)planetary force of gravity that has created a new set of conditions and

[155] Using data about Ceres retrieved from Williams (2016).
[156] Figures given to 2 decimal places.

properties around an otherwise unchanged landing craft, this new context and the forces therein giving the landing craft ~1/6358th of its terrestrial gravitational force. Similarly, if we were to transfer the landing craft to the context of Jupiter, its gravitational force would become 3.48x10^{16}, meaning Hyabusa2's gravitational force has now increased by ~318 times that of its terrestrial context. Considering Hyabusa2 in this regard serves to highlight the complexity posed through shifting extraplanetary contexts.

Alongside recognising how (extra)planetary forces shift the material conditions of objects and their subsequent relations – as illustrated above – we may go further in our engagement with terracentrism and begin to interrogate broader philosophical questions, not least of which involve ethics. This area is particularly pertinent to the questions outlined above and a turn to the extraterrestrial demands we engage with (and reconsider) ethical principles and guidelines. Ethics as they exist *vis a vis* contemporary society have developed within a terrestrial context. Consequently, venturing beyond Earth's remit forces us to consider these principles anew. A justification behind calls for asteroid mining (and interplanetary mining more broadly) lies in the (presently) apparent lack of life on other worlds, never mind asteroids. However, this justification may be critiqued in its terracentric disposition. Critiqued due to its adherence to conceiving of a lack of life as we know *on Earth* and through adopting an Earth-bound ethics and applying them elsewhere in the solar system. Is this ethical code sufficient for elsewhere within the solar system or should we work towards a Martian ethic for Mars, a Jovian ethic for Jupiter, and so on? This point is worth bearing in mind throughout the rest of the thesis due to some of the arguments and discussions made by asteroid mining advocates and opponents alike.

This is but one small example in how recognising geography's adherence to terracentric onto-epistemologies is troubled through engaging with and thinking through (extra)planetary forces, questions of verticality, and the questions they necessarily beget. It highlights our need to account for (extra)planetary forces in our discussions and framings of society, materiality, and extraterrestrial socio-politics. Furthermore, to engage critically with these forces requires that we foreground them in our analyses rather than merely nod towards them as a background upon which the social and material play out. Indeed, to work with and through the (extra)planetary is to explore how the social and material are shaped by, and dependent upon, these forces.

5.5 The 'Frontier' Revisited

This chapter has explored the ways Outer Space and asteroid mining are being (re)created as 'frontiers' through various means. It began by looking at how the 'frontier' is being (re)imagined through the perpetuation of discourses that frame asteroids and Outer Space in multiple ways, drawing upon certain settler colonial histories and, through this, encouraging the disimagination process to marginalise or silence alternative imaginaries. The conversation then turned to consider how the materialities of asteroids are contributing to the frontier imaginaries invoked within the NSE: how the industry's focus has variously shifted from mining (rare) metals, to water, to becoming way stations, each being articulated as a material enabling the expansionary logics of capitalism and extractivism to continue, along with their attendant processes of capital investment and accumulation.

However, these imaginative and material processes are disrupted when thinking with or through the provocations offered by terracentrism: new (extra)planetary processes having to be accounted for and considered. By thinking critically about how asteroids become

'knowable' in these contexts and the reliance on creating a provisionally stable reality in an otherwise unstable and dynamic environ, the discourses of the NSE become unsettled. Through this, the capitalist, Eurocentric, and terracentric assumptions of the NSE are decentred: speculative valuations that assist in maintaining the expansionary logics of capitalism are muted, the histories underpinning these futures made explicit, and the terracentric logics of extraction are thrown into uncertainty. Crucially, it opens the 'frontier' as a site wherein new onto-epistemological possibilities can be posited and established, the normative assumptions underpinning the *de facto* futures of asteroid mining and Outer Space being rendered unstable and up for contestation.

Chapter 6: Enclosure, Territorialisation, and Extractive Excess

6.1 Introduction

The topics covered in the preceding chapter – of what constitutes an asteroid's material body, how these are being related to and made sense of, and the provocations these offer for terracentrism – have all, to varying degrees, dealt with the 'opening' of the asteroid 'frontier'. We saw how asteroids are being opened to reimagining: their uses and the purported opportunities this (re)creates. Similarly, taking asteroids and their myriad compositions into account enabled a space to open through which debates around terracentrism and the issues this poses in an (extra)planetary context could be engaged with. However, any conversation regarding a 'frontier'[157] does not solely focus upon processes of 'opening', though these are doubtlessly important through their (re)creating and subtending the frontier imaginary of any given site. An equally important aspect of frontier formation and its attendant socio-material practices is the 'closing' of the frontier and the materials therein in various ways. Thus, it is insufficient to merely discuss the 'opening' of the asteroid frontier without similarly discussing its 'closing' also (Li, 2014: Steinberg, 2018).

This chapter engages with closing or enclosure and is divided into two sections. The first pays attention to the acts of enclosure that are primarily permitted through policy and private discourse. This section begins by considering how a rights regime is being created to enable extractive activities before moving on to look at asteroid mining legislation of various guises more specifically. It then moves on to consider the public-private[158] discourses that are

[157] Something Outer Space and asteroids are being increasingly (re)framed as through growing NSE activity and advocacy. This is being done through organisations such as the *Space Frontier Foundation*, *spaceresources.lu*, (inter)national legislation (e.g. U.S. SPACE Act, the Artemis Accords, etc.), and non-state announcements and coverage.

[158] Used here to signal that these discourses are not only advanced by private actors, having advocates present throughout civic space agencies also.

used to advance and subtend acts of celestial enclosure, looking first at economic/capitalist arguments before turning to look at how asteroid mining is being set up as a 'green imperative'. The second section shifts the focus to matters of material waste. This section is most prudent due to waste being an inherent part of any extractive frontier (Bridge, 2000: Mumford, 1934: Reno, 2015). This section begins by exploring how 'frontiers' can operate as sites of invisibility and how we may begin to uncover and interrogate some of the implications of these processes. The conversation then turns to explore how these issues are being either managed or ignored by those in the NSE sector before moving on to think through some of the material implications of asteroid mining waste: from the volumes and materialities of this waste to the effects on frontier navigability. This section finishes with a discussion on how material waste can operate as a destabilising force in conversations on asteroid mining and Outer Space futurity through decentering capitalism, Eurocentrism, and terracentrism.

6.2 Enclosure and the Territorialisation of the 'Final Frontier'

This section is organised around two key aspects of the enclosure process. The first dimension is the role(s) played by legislation of various forms. These documents act as a set of discourse markers that officiate understandings of the extraterrestrial 'frontier' through policy: they signify what may be deemed appropriate through a codified rights regime for asteroid mining. Perhaps most important is the ability of these documents to 'territorialise' asteroids and Outer Space more broadly. They create a rights regime that is affixed to an asteroid's surface, thereby rendering the 'final frontier' provisionally navigable through a relational onto-epistemology that is derived – in part – from an asteroid's orbital movement. The second dimension organising this section concerns itself with the public-private discourses mobilised by NSE actors to advocate and accelerate these acts of enclosure. Specifically, these

discourses are centred around two key principles: expansionary logics for capital accumulation and the (re)creation of a 'green imperative' to justify the commercial exploitation of asteroids and other celestial bodies.

6.2.1 Creating a Rights Regime and the Territorialisation of Outer Space

I first consider how a legal rights regime is being created in Outer Space and how this process, in turn, operates to territorialise 'the final frontier': creating a series of relationships that render Outer Space provisionally navigable that is contingent upon asteroids as much as mining companies and their technologies. There is broad consensus within the aerospace sector – both civil and private – that a legal rights regime is required that addresses current issues, many agreeing that the *Outer Space Treaty* is outdated and no longer fit for purpose. Given the changes that have occurred in the space sector since the treaty's creation – most notably, the founding and increasing influence of private industry – what is and is not permitted in Outer Space is currently undergoing much debate. A legal commentator from the USAF at the *SFF* conference argued that asteroid mining would be permitted under the *Outer Space Treaty* as it is an "enabling document" that does not expressly forbid asteroid mining, making this permissible as the "Lotus principle . . . means anything that isn't prohibited is permitted"[159]. They went on to argue that "treaties are law that sovereign states choose to follow and can't pass domestic legislation against it . . . [and] the Lunar [and OST] treaty doesn't prohibit mining, so why would the US?". Consequently, there have been calls from both inside and outside of the industry for a clear property rights regime where ownership and control can be guaranteed and assured.

[159] Quotes taken from participant observation notes of the SFF conference.

Indeed, as Helen – an aerospace industry consultant that has worked with multiple NSE businesses in the US – noted in our interview, regulation is necessary within the industry as "[it's] not just who gets to do what but . . . to what degree". Here, Helen gets straight to the heart of the matter *vis-à-vis* current debates on asteroid mining legislation: policy is fundamental in its ability to reassure investors and procure subsequent seed capital through creating a legal rights regime that helps to mitigate some of the 'risks' involved in mining investment (Bridge, 2004). Specifically, this 'rights regime' simultaneously operates as a mode of regulatory exclusion and a market mechanism that excludes those who cannot afford access (Li, 2014: Tsing, 2003). Moreover, this rights regime shifts the discourse from one of common ownership to *exclusive* ownership, thereby instigating and driving the act(s) of enclosure that permit capitalist access and the exploitation of asteroids (Redclift, 2006: Wood, 2017). However, we should note here that some private actors are wary of regulatory legislation. Whilst they acknowledge the benefits of a legal framework, some – such as a keynote NewSpace financier at the *SFF* conference – have argued that an "overbearing regulatory regime kills off innovation by accident" and, in some instances, would see the sector "answer [issues] when it comes to it. If there's a desire to explore and discover, it'll carry on"[160]. Despite this caveat regarding attitudes to regulatory legislation, there seems to be a broad consensus that a rights regime is required and many NSE actors have welcomed legislative developments at both the national and international levels[161]. The welcoming of such legislation is hardly surprising given that numerous NSE actors have claimed to have some influence in shaping these policies, whether this was the (now-former CEO) of DSI[162],

[160] Quotes taken from participant observation notes of the SFF conference.
[161] Specifically, we may think of domestic space policies such as the US SPACE Act 2015 and international legislation such as the *Artemis Accords.*
[162] From comments they made at the *ESPI* conference.

the *Space Frontier Foundation*[163], or the involvement/interest of the 'Big 4' accountancy firms[164]. Indeed, whilst at the *ESPI* conference, the former-CEO of DSI noted how they "and [some other NSE actors put] on an event for Obama and his people so we could tell them what needed to happen to make this happen". Through their purported influence on policy and continued lobbying efforts, private space actors perpetuate a normative discourse that takes for granted capitalism and Eurocentrism. Through their codification, these assumptions perpetuate the process(es) of disimagination: they do not only physically enclose Outer Space but operate as a mode of *imaginative* enclosure also. They reproduce normative assumptions of who is removed, excluded, or silenced in matters of extraterrestrial ownership.

Moreover, this legislation does not simply operate to (re)produce normative discourses of the centrality of capitalism and Eurocentrism but operates as a means by and through which Outer Space is rendered provisionally navigable by and for private actors. Outer Space diverges distinctly from terracentric modes of navigability: where there is (broad) spatial fixity by and through which we navigate our daily lives and industry can exert control over certain areas through erecting physical barriers to 'their' resources (Li, 2014). However, this normative logic of terrestrial navigation is confounded when venturing off-Earth: the Earth rotates on an axis whilst travelling through its own orbit amongst the orbit of other planet(oid)s (Jones, 2021)[165]. Given this complexity, legislative documents and the rights regime they (re)impose function to 'territorialise' asteroids and Outer Space more broadly. Through their affixing rights to an asteroid's surface – rather than attempting to control the

[163] Who have combined their efforts with the *National Space Society* to form the *Alliance for Space Development* to specifically influence space policy (see http://spaceref.com/news/viewpr.html?pid=45124 for more details).
[164] Data relating to the 'Big 4' and other accountancy/banking firms is explored later in the chapter.
[165] Indeed, this confounding of normative navigation is neatly surmised in Orson Scott Card's *Ender's Game* where we are reminded that there is no 'up' in space.

space around it – these documents and the extractive rights they assert render Outer Space provisionally navigable through a relational onto-epistemology that is derived – in part – from an asteroid's orbital movement. This process allows for a mode of spatiality to be (re)created in Outer Space by rendering each planet(oid) its own distinct territory, where rights can be exerted and expressed where the complexities of the extraterrestrial may otherwise confound them.

Having considered the way(s) in which legislation is being used to enclose Outer Space and (re)produce a system wherein and whereby capitalist and Eurocentric discourses can be perpetuated and the confounding modalities of the Outer Space environ rendered provisionally navigable, I turn now to look more closely at asteroid mining legislation itself.

6.2.2 Asteroid Mining Legislation

Asteroid mining legislation is being used to discursively enclose Outer Space and create a legal rights regime around asteroids. However, as noted above, this legislation does not simply function to implement a series of neutral rules but is influenced by the lobbying efforts of powerful elites with vested interests: these lobbying efforts shaping legislation that (re)creates a normative discourse of exclusion that favours capitalist and Eurocentric framings of property relations and ownership. Consequently, I turn here to consider some of this legislation and how this (tacitly) permits the privatisation and enclosure of Outer Space, enabling asteroid mining to various degrees. We should note here, however, that much of the legislation enacted – or undergoing the ratification process – is frequently vague in the language used. This is for two main reasons. Firstly, this nascent legislation is designed to be sufficiently vague to avoid curtailing potential businesses and their interests (we may think back to the comment on an "overbearing regulatory regime that kills off innovation by

accident" here). Secondly, and perhaps more importantly, vague language can be used as a means of avoiding direct contravention of signatory commitments in the *Outer Space Treaty*.

Although the *Outer Space Treaty* is usually regarded as prohibiting ownership of Outer Space resources – including asteroids – many have argued that the 1967 treaty is ambiguous and does not expressly prevent *private* ownership. As noted above, some in the NSE sector – such as the legal commentator from the USAF – view the *Outer Space Treaty* as an "enabling document" that permits asteroid mining through the "Lotus principle: anything that isn't prohibited is permitted"[166]. Indeed, the *Outer Space Treaty* was discussed by NSE actors – including a director at NASA – as a "regulatory issue" that needed addressing so that the "need to deregulate" Outer Space could be realised[167]. Indeed, through mobilising the "Lotus principle", speakers argued that there were no rules against asteroid mining, stating that "the *Outer Space Treaty* and *Lunar Treaty* don't prohibit mining, so why would the US?". Given the ambiguity of the *Outer Space Treaty*'s application to private ventures, there has been a burgeoning set of legislation at both national and international levels.

Indeed, due to this ambiguity, numerous nations have begun passing (provisional) legislation to facilitate the private exploitation of asteroids. Nowhere is this more explicit than in Luxembourg's *Space Resources Act*, with Article 1 declaring "Space resources are capable of being exploited". This sets out in unambiguous terms the intention of such documents to begin officially enclosing and privatising Outer Space and asteroids. Luxembourg's legislation – along with other legislation such as those enacted by the USA and India – seek to encourage a 'pro-growth' environment *vis-à-vis* the NSE. They aim to do this through acting, in part, as

[166] Quotes taken from participant observation notes of the *SFF* conference.
[167] Quotes taken from participant observation notes of the *SFF* conference.

clarificatory documents that allow for the legislative 'certainty' demanded by investors (Bridge, 2004). This is made expressly clear in India's draft legislation, which states in the preamble: ". . . it was considered that introduction of a specific legal regime should only enable further growth of space activities in India, rather than merely a regulatory or restrictive regime." This sentiment is also found in the *US SPACE Act 2015*, with the preamble expressing similar aims, declaring the purpose of the Act being: "To facilitate a pro-growth environment for the developing commercial space industry by encouraging private sector investments and creating more stable and predictable regulatory conditions, and for other purposes." (SPACE Act). Interestingly, although these legislations operate to permit asteroid mining in their respective national context, each is sufficiently vague so as not to overtly refute the *Outer Space Treaty*. Indeed, the *US SPACE Act* has an explicit section designed to refute allegations that it may contravene its commitments under the *Outer Space Treaty*. Specifically, Section 403 of the Act is entitled 'Disclaimer of Extraterrestrial Sovereignty', in which it states: "It is the sense of Congress that by the enactment of this Act, the United States does not thereby assert sovereignty or sovereign or exclusive rights or jurisdiction over, or the ownership of, any celestial body." (Section 403 SPACE Act). This is an overt means whereby the legal ambiguity *vis-à-vis* the *Outer Space Treaty* is avoided whilst the Act itself signals to private venture capitalists that they will be able to commence asteroid mining from the USA, among other nations. This sense of privatising Outer Space and creating a rights regime whereby asteroids can be mined by private actors has gained further traction through the *Artemis Accords*. Designed by the USA to facilitate international cooperation to realise the goals set out by their *Artemis Programme*, the Accords are designed ". . . to enhance the governance of the civil exploration and use of outer space with the intention of advancing the Artemis

Program."[168] However, this comes with a caveat: the Accords aim to "to create a safe and transparent environment which facilitates exploration, science, and *commercial* activities for all of humanity to enjoy [emphasis added]"[169]. Thus, even when purportedly striving for something 'for all humanity to enjoy', normative assumptions as prescribed by a neoliberalised rationale – in which everything is open to market forces and actors – can be found amongst the central tenets of both national and international legislative documents.

Consequently, the role(s) of legislation in maintaining and perpetuating the enclosure of Outer Space, and asteroids more specifically, can be observed through the normative assumptions held within both national and international legislation. These documents have begun (re)creating a provisional rights regime in Outer Space, reinforcing capitalist and Eurocentric modes of property rights and ownership, shifting from communal to private ownership (Wood, 2017). These central modes of thought that (re)structure human-asteroid relations operate to reduce investor 'risk' by 'creating more stable and predictable regulatory conditions' (US SPACE Act, 2015), something demanded by traditional and speculative mining projects alike (Bridge, 2004: Li, 2014): these legislative manoeuvres also territorialising Outer Space through rendering it provisionally navigable through relational onto-epistmologies that arguably move beyond terracentric conceptions of spatiality to account for the complex environment of Outer Space. However, the enclosure of Outer Space – and asteroids more specifically – is not structured through legislation alone but is actively (re)enforced through the discourses of public-private actors and the materials they (re)produce. It is these discourses I now turn to consider.

[168] *Artemis Accords, Section 1.*
[169] Taken from NASA information website https://www.nasa.gov/specials/artemis-accords/index.html (Dunbar, 2021)

6.2.3 Capitalising From the 'Final Frontier'

Having considered some of the ways that Outer Space is being enclosed through various national and international legislation that seeks to create an exclusionary property rights regime (Bridge, 2004: Li, 2014: Tsing, 2003), I turn now to consider how this is being driven through discourses of capital: the principal means by and through which these actors are seeking to enclose Outer Space – thereby permitting asteroid mining. Specifically, through (re)framing asteroid mining and Outer Space as a site of immense profit potential, NSE actors and asteroid mining advocates have (re)created narratives around utilisation and economic waste to subtend this discourse of the 'need' for enclosure (Woods, 2017).

To advance their interests in enclosing and profiteering from the 'frontier' of Outer Space, NSE actors frequently link the idea of not engaging in asteroid mining or leaving Outer Space alone as a 'wasteful' activity. A spokesman from Deloitte argued in their talk that "We'll either look back and say we made it or look back and think we blew it"[170] and an interviewee rhetorically asked "We have all of these resources just lying around to be used, why would we just leave them floating around there?" (Steven – an NSE consultant involved in space advocacy campaigns). Indeed, to hammer home this idea of wasting an economic opportunity, the NSE sector and associated bodies produce an abundance of material to outline the massive 'profit potential' of privatising Outer Space. Sites such as *Visual Capitalist* have pages on how 'There's Big Money to Be Made in Asteroid Mining' and cite the estimated net worth of asteroid materials as being US$700 quintillion (Desjardins, 2016). However, it is worth noting here that these figures are based on mineral valuations as they are at present. When the idea of price crashes induced through the mass importation of minerals was raised

[170] Quote taken from participant observation notes of SFF conference.

at the conference, attendees were encouraged not to worry. Several speakers (one a Deloitte spokesman, one an NSE advocate/consultant, and another the CEO of an NSE company) reassured us that this would not be an issue due to the minerals' intended use in Outer Space, meaning asteroid mining could not crash the market as their materials would not flood the terrestrial market. Another speaker – a board member of a satellite company – also noted "that wouldn't be allowed to happen . . . we'd create a system to stop that". As James – a NewSpace advocate, consultant, and head of his own NSE company – discussed in our interview: "Capitalism's a tool, you know? It's not some religion or ideology like some people say, it's a tool. So [we can] change it if it isn't working . . .". Indeed, during the *Space Frontier Foundation* conference, a panel was held called 'Space: A trillion dollar market? [sic]". As the title suggests, members discussed the various means through which the NSE's valuation could be increased, noting that asteroid mining would be part of this economy. A slide was shown that had a series of projected market valuations for the 2040s. A range of values were given from different sources: 'various sources' (2017) estimated US$329-350 billion; Goldman Sachs was cited as US$1 trillion; Morgan Stanley estimated US$ 1.1 trillion; and Bank of America Merrill Lynch had estimated US$2.7 trillion[171]. The profit-potential is not simply expressed through quotes such as these but is made more tangible through the production of infographics such as Figure 5.3. Here the idea of asteroid mining's profitability is given more traction through the physical representation of various asteroid valuations, all of which are purportedly worth more than Earth's entire economy. Similarly, the *Space Frontier Foundation* conference had artistic renditions of exoplanets for sale in the foyer[172], making

[171] Figures taken from participant observation notes of the SFF conference.
[172] Unfortunately I was unable to take a picture of this display: I took my phone out and was about to take a picture when I was asked (i.e. told) not to take pictures of the display if I was not going to buy any of the artwork.

the 'frontier' more tangible whilst (re)producing a colonial, Eurocentric imaginary of the 'bountiful emptiness' of these spaces[173].

The supposed profits involved in asteroid mining, as expressed through the figures and infographic above, provide a key means by and through which the enclosure of Outer Space is argued for by those within the NSE. Indeed, alongside the scale of capital accumulation that asteroid mining would supposedly permit being used as an argument to support the discourse of enclose, some suggested that this profit-potential would see wealthy actors influencing legislation and regulations. As James said during our interview "There's so much money on the table . . . the powerful will just override the rules or . . . more likely just make sure rules like that aren't in place". Here, James' comment illustrates how even those in the NSE recognise that those with capital will shape policy through lobbying if they can, as the then-CEO of DSI had bragged of his company doing at the *ESPI* conference in 2018[174]. This former-CEO went on to express their vision for Outer Space regulation, saying "we don't need regulations based on outdated, academic, non-real world information, based on irrelevant historical examples and socialist philosophies that stifle creativity"[175]. The implication in this statement is clear: that the 'best' form of regulation would adopt and advance capitalist interests, oppugning the idea(s) of Outer Space as a shared resource[176].

The idea of economic 'waste' by leaving asteroid 'resources' alone (such as in Steven's point above) is one strand of the argument for enclosure proposed by capitalist interests. The

[173] Here we may think of Romantic-period artwork and its depiction of various colonial 'frontiers' of its time.
[174] Taken from participant observation notes of the *ESPI* conference and discussed in the previous subsection.
[175] Taken from participant observation notes of the *ESPI* conference 2018.
[176] Indeed, this same former-CEO argued that there the "3 keys to the frontier are: 1) Regular, reliable and low cost access to space; 2) Use of space resources for whatever purpose, and; 3) Governments that support an open human frontier in space". Once more, points 2 and 3 represent the desire to privatise Outer Space through the idea of 'utility value' (Woods, 2017) and the idea that governments and their associated legislation will be lobbied and pressured by private interests.

second strand that operates through the idea of economic 'waste' to subtend the capitalist discourses towards the enclosure of Outer Space is the co-option of the common heritage principle. The initial manifestation of the common heritage principle – such as that enshrined in the *Outer Space Treaty* – posits that no individual may enclose or lay claim to a common, that these areas should be held for the enjoyment and benefit of present and future generations. However, mining firms – including asteroid mining companies – have sought to exploit this principle through shifting the narrative, arguing that private and state-sanctioned mining initiatives produce a 'benefit' for all people through their exploitation of various materials (Steinberg, 2018). Indeed, a spokesman from Nanoracks at the *SFF* conference claimed that private ventures were "democratizing [sic] space: commercial access lowering the barriers to customers all over the world". The idea of common benefits was noted by various NSE advocates but James perhaps surmised this position best when they commented that asteroid mining would provide enough resources "to provide all humans with a standard of living equivalent to . . . Western democracies". Some have attempted to rebut this perversion of the common heritage principle by arguing that the global commons also belong to future generations (Buck, 1999: Steinberg, 2018). However, when this point was raised with respondents or at conferences, it was argued that the 'benefits' of extraction would 'trickle down' to people and through to future generations. Indeed, one speaker used this point during their presentation, saying "Does space belong to everyone? No. It should but it doesn't"[177]. However, the most striking example of this capitalist truism was Steven's response to the idea of Outer Space as a global common: "That's bullshit. It's nice flowery language but we don't do that on Earth, what makes anybody believe we'll do that in space?".

[177] Taken from participant observation notes at the *SFF* conference.

This disconnect between the "bullshit" public-facing discourse and 'off-stage' frankness also became apparent with several military personnel who spoke at the conference. Occupying different senior roles within the US military, these actors advocated for the privatisation of Outer Space, one noting that he "doesn't know of a future where we can maintain air superiority without space superiority" and the other adding "Why do we do space at all? To support our people at the pointy-end of the spear". This rhetoric was echoed again by a former-Colonel turned consultant, who commented on the NSE "Uncle Sam is running out of money and sees the growing threat. So if you show capability, he'll notice". This (re)framing of Outer Space further indicates a growing disconnect between the public-facing rhetoric of Outer Space as a common-pool resource and calls to privatise and enclose Outer Space, linking it through to the military-industrial complex and notions of national security.

This rejection and subsequent co-option of the common heritage principle by private NSE actors is a site wherein and whereby the 'frontier' is conceptually enclosed as capitalist interests seek to replace ideas of common ownership and management with a discourse that actively promotes enclosure and capitalist expansion and exploitation (Tsing, 2003) of asteroids and the wider Outer Space environment. Whilst this is a key means by and through which the privatisation and subsequent enclosure of Outer Space is being made seemingly palatable and consent for this being manufactured, it is not the sole discourse NSE actors are using to realise their goal of enclosure. Another discourse being perpetuated and mobilised to help realise this goal is the discourse of a 'green imperative'. I will now turn to discuss this.

6.2.4 Greening Extraction: Outer Space and the 'Green Imperative'

Operating alongside the fiscal arguments for the enclosure and privatisation of Outer Space is the mobilisation of a 'green imperative' discourse. This discourse sees multiple and

variegated claims come together in an attempt to position Outer Space and asteroid mining as a 'green' solution to contemporary issues of ecological destruction. Indeed, whilst terrestrial mining companies have often sought to minimise resistance to their operations' social and environmental impacts through 'greening' their image (Gamu and Dauvergne, 2018: Parsons et al., 2014), these impacts can be (in)directly observed and called out. However, asteroid mining – and extraterrestrial extraction more broadly – is unfolding in an area of 'invisibility'; an imagined space, the interactions with(in) which the characteristics and dynamics are narrated and (re)shaped by those in power (Childs, 2019: Gamu and Dauvergne, 2018). This came through during interviews with NSE actors and can be found throughout grey literature associated with the asteroid mining sector. I will now consider some of the means by and through which this 'green imperative' is being (re)created by NSE actors and attendant materials[178].

A key argument used to prop up the 'green' credentials of asteroid mining is the moral imperative: one that frames asteroid mining as fundamental to keeping the Earth habitable through the 'off-worlding' of polluting industries. Matloff et al. dedicate an entire chapter of their book *Harvesting Space for a Greener Earth* to the moral argument for space-based industry and extraction. In it they write:

> ". . . in order for humans to prosper and be good stewards of the planet and its myriad life forms, they must stop destroying the environment that gives it life. But how do we accomplish this goal and maintain all of the positive aspects that come from our twenty-first-century technological civilization [sic]? The answer is pretty

[178] Press releases, advertising materials, etc.

> simple. We must place heavy industry, with all of its inevitable pollution, in a place that is already hostile to life and in which life will almost certainly never arise – in space or on the Moon. A space-based infrastructure is not only possible but also essential if we are to restore our home planet and turn it into a safe place to live, pollution free." (2014; p.12).

This moral argument for the relocation of heavy industry into space is not consigned to books and papers by space advocates and engineers. This strand of thought is firmly embedded in discussions of Outer Space futurity and the role it will play in preserving Earth. Indeed, Jeff Bezos – one of the three billionaires looking to make space their personal domain[179] – has made a similar point regarding the moving of heavy industry into Outer Space:

> "Our descendants are going to move all heavy industry off of Earth — all the polluting industry will be done in space where we have infinite resources for all practical matters and Earth can be zoned, light industry and residential ... Earth can be this amazing garden."[180]

This idea of Outer Space as a veritable cornucopia of 'infinite resources' becomes enmeshed with the moral dimension of the 'green imperative' in two distinct ways. Firstly, advocates link this through to the removal of polluting industries, to preserve Earth and "to provide a

[179] The other two being Elon Musk and Richard Branson.
[180] Speaking at *Amazon India* event, available at https://www.youtube.com/watch?v=jzfXlg-wyUU

brighter future for all of mankind"[181]. Secondly, the moral case is linked through to raising living standards for everyone. Whilst Matloff et al. (2014) note at the start of their book that to provide everyone with the same standard of living would see a dramatic increase in greenhouse gas emissions[182], NSE advocates such as James – the NewSpace advocate, consultant, and head of their own NSE company from earlier – argue that asteroid mining provides a neat solution to these problems:

> "The fact of the matter is that if you look at the solar system, it's nonsense [that there aren't enough resources for a viable future], you know? It's . . . silliness to imply that . . . all humans, we have enough – in the solar system – resources to provide all humans with a standard of living equivalent to . . . Western democracies . . . We have huge numbers of people and we have resources that do far less environmental damage and we can get it at a far lower cost, so we can provide a much better standard of living for a much larger number of people, at much less damage than we've ever done in history . . ."

Here, James' comments clearly outline an argument used by asteroid mining advocates to subtend the 'green imperative' discourse: asteroid mining has to happen not only to save the Earth from ecological decline and climate catastrophe, but also to raise the living standards of everyone at the same time. With this in mind, we can see how the characteristics and dynamics of asteroid mining are being narrated and (re)shaped by those in power (Childs,

[181] Quote retrieved from analysed website material (DSI (2017), 'Who We Are'. This webpage is no longer accessible).
[182] A problematic assumption in itself, though there is insufficient space here to delve into the issue.

2019: Gamu and Dauvergne, 2018) to (re)produce within this imagined space a utopic futurity: one in which scarcity ceases to be an issue without the attendant issues of pollution, whilst further entrenching and legitimising a capitalist mode of production and exploitation.

Beyond the moral arguments advocates use to promote their industry, asteroid mining is advanced through a 'green imperative' further through linking their activities to 'sustainability' and market demands for certain choice elements that are required for renewable technologies. Thus, rather than simply framing the industry as a site of capital accumulation and immense profit potential, the industry has attempted to diversify its appeal further through speaking to demands for renewable technologies. If we look back to Figure 5.1 in Chapter 5, Planetary Resource's infographic states the 'need' for platinum group metals for advanced materials, catalytic converters, and notes that one in four manufactured goods requires these metals. This is not simply designed to appeal to market demand (although this is a large part due to the private nature of these ventures) but to align asteroid mining narratives to ideas of a green futurity. Indeed, the narrative links being made between asteroid mining and sustainability are not limited to terrestrial sustainability but is a term being applied to the provision of materials to the cis-lunar economy. DSI's website makes this clear: "This is the goal of Deep Space Industries: in-space delivery of the right materials, to the right place, for the right price, to support the sustainable expansion of Earth's economy into space."[183] Not only does DSI position their activities as a means of 'support[ing] the *sustainable* expansion of Earth's economy into space [emphasis added]" but links this back through to the utopic futurity outlined above: "We are journeying to unknown frontiers, and

[183] Information retrieved from analysed website material (DSI (2017), 'Asteroid Mining: An Unlimited Future for All Mankind'. This webpage is no longer accessible).

pushing the limits of technology to provide a brighter future for all of mankind."[184] This final quote from DSI epitomises the promises made by asteroid mining advocates to advance their interests. Using the 'all of mankind' as a hook that echoes the *Outer Space Treaty*'s sentiment, they promise a 'brighter future': something that is deliberately ambiguous and allows people to project their own hopes and interpretations upon the statement but, when taken with the rest of the material, links back through to the 'green imperative' used to justify asteroid mining. Indeed, this 'green imperative' is not simply being applied to a terrestrial context but is being linked to extraplanetary futurity. Alongside DSI's above claim of expanding the Earth's economy into space, NSE actors are also attaching their arguments for asteroid mining to 'sustainable' multiplanetary exploration, Steve – the NSE consultant involved in space advocacy campaigns from earlier – commenting that "There is no alternative. There's literally no alternative. We cannot sustainably go to Mars on a continuous basis and on a permanent basis unless we're using resources available in space".

Thus, through linking asteroid mining through to a 'green imperative' through a specific mode of corporate social responsibility – one that purports to be engaged in these activities to secure 'a brighter future for all of mankind' – asteroid mining companies and advocates (re)produce a new site by and through which demand can be manufactured and Outer Space made into a site of capital accumulation. Another aspect of the narrative control that the powerful exert on this imagined space are the risks involved and the way(s) waste and its materialities are 'managed'. It is this topic I now turn to discuss.

[184] Information retrieved from analysed website material (DSI (2017), 'Who We Are'. This webpage is no longer accessible).

6.3 The Material 'Afterlife' of Asteroid Mining

Having considered some of the manifold means by and through which Outer Space – and asteroids more specifically – is being enclosed and territorialised to permit the extraction and subsequent exploitation of a variety of materials, I turn now to consider the 'afterlife' of these activities. Whilst various NSE actors have decried resistance to asteroid mining as 'wasteful' in its own sense[185], this section focuses upon 'waste' in its material guise. It outlines some of the issues posed by asteroid mining projects, the lack of engagement with – or silencing of – this topic by various actors, and heavily engages with the speculative methodology to begin thinking through the implications of asteroid mining waste. The section begins by exploring how the asteroid frontier operates as a site of invisibility before moving on to a more detailed discussion of how the issues of material waste are being managed or ignored. Following this, the materiality and scale of this waste is discussed. The section then moves on to consider the spatio-temporal ramifications this waste poses for Outer Space futurity before finishing with a subsection on how the materialities of asteroid mining waste can operate as a destabilising force for *de facto* assumptions of the 'final frontier'.

As noted previously, Outer Space is currently being (re)framed as a frontier that is being enclosed by actors through a variety of methods with the intention of profiteering from the resources in this new 'frontier' (Squire et al., 2021). This is made abundantly clear by various asteroid mining companies and associated actors. DSI explicitly stated that it "is industrializing [sic] the frontier"[186] whilst the Asteroid Mining Corporation (AMC) states that one of its goals is "to be pioneers settling new lands and forging new destinies for mankind in

[185] This argument was made by nearly every NSE interviewee and came up in conference talks also. To resist the privatization of Outer Space was deemed to be 'a waste' of opportunity: both the opportunity to expand into new industries that their conceptions of Outer Space futurity was contingent upon and the opportunity to accumulate vast sums of capital.

[186] Information retrieved from analysed website material (DSI (2017), 'Who We Are'. This webpage is no longer accessible).

the final frontier"[187]. Through conceiving of Outer Space as a 'frontier', it becomes (re)imagined and constructed as a site of 'bountiful emptiness' that is simultaneously 'empty but full': devoid of people, histories, and claims whilst full of potential for new use, capital investment, and profit (Bridge, 2001: Li, 2014).

However, despite the expansionary logics that seek to enclose the 'frontier' and position it as a site of 'bountiful emptiness' (Bridge, 2001: Li, 2014: Redclift, 2006: Steinberg, 2018: Tsing, 2003), a crucial dimension of the 'frontier' is its ability to function as a site of invisibility. The 'frontier', whilst a 'bountiful emptiness', is always beyond the horizon, always 'elsewhere'. This spatial and temporal distance allows for various (inter)actions to be played out – both imaginatively and materially. This invisibleness allows for the (re)creation of narratives around various materials, for speculation to occur, and for the frontier of Outer Space to be "already fully leaden with cosmic dreaming, theological wonderings, and science fiction fabulations" (Kearnes and van Dooren, 2017; p.). This speculation and subsequent narrative-creation has enabled NSE actors and private companies to advocate for the enclosure of Outer Space (see above discussion). However, most importantly for the conversation at hand is how this invisibility and the attendant narratives enable various processes and issues to be omitted. Specifically, the present (re)framing of Outer Space operates to privatise that which is deemed 'valuable' whilst externalising the risks posed by mining excess, a common theme that links the logics of mining and capitalism (Mumford, 1934). Indeed, terrestrial mining generates wastes of between 65-90% depending on the processes used in extraction (Bridge, 2004: Wieszczycka, 2018). Whilst it is common practice in extractive industries to dump waste materials into common pool areas to render it an

[187] Information retrieved from analysed website material (AMC (2020), 'About The Asteroid Mining Corporation', https://asteroidminingcorporation.co.uk/about-us

externality to the mining process (Bridge, 2004), there is a resounding silence around this issue in the asteroid mining sector and attendant literature. This is due to a combination of actors regarding the matter "as a non problem [sic]" (Mark) and, more specifically, using the Outer Space frontier's 'invisibility' to dismiss the issue, as Steven neatly outlined in their response to the issue: "Who cares? We can't see it". However, with the dismissal of asteroid mining waste through its being provisionally 'invisible' – beyond the horizon – NSE actors sought to manage or ignore waste through a variety of means. It is this that I now turn to discuss.

6.3.1 Managing or Ignoring Asteroid Waste

As noted above, the provisional 'invisibility' of a 'frontier' allows for certain issues to be elided in attendant discussions, this invisibility allowing a blasé dismissal of waste and its potential ramifications, as Steven's above comment neatly demonstrates. Indeed, part of this apparent silence around waste could be attributed to the nascent nature of the asteroid mining industry, James having noted that "There's not a lot available on this because most of the concepts of asteroid mining are at such early stages. Most of the asteroid mining companies were/are focused on nearer term technologies". However, through the course of this research respondents were asked how asteroid mining waste could be managed and what issues this discarded material may pose for the viability of present and future activities in Outer Space. Alongside this, answers were also searched for through the materials collected and analysed as part of the research process. What emerged was a mixture of attempting to manage this future waste – whether through its commodification or collection – and attempts to ignore the issue. I will discuss each of these processes in turn.

The first of these processes was the attempts to manage asteroid waste. This process could be divided into two categories: some actors and material suggested that the 'waste' could be utilised[188], whilst others suggested it could be collected and rendered safe through this process. With the former of these two 'management' strategies, actors suggested that asteroid waste could actually have productive uses in and of itself. The former-CEO of DSI suggested that this material would be collected and repurposed for other space-based projects, waste becoming an ingredient in building material they referred to as 'astrokrete'[189]. In a similar vein, Gary, a NASA consultant that works with and promoted NSE SMEs, suggested that asteroid waste could be used as a propellant in the Outer Space economy "I am certain that all materials in space have some sort of value…worst case remember that propulsion is possible by pushing an object with mass away from you, so if nothing else you have reaction mass regardless of its composition." When engaging with NSE actors on this topic, speculating that 'waste' could be commodified and a purpose found for it was a common trope, meaning waste would not be discarded and therefore would not exist as a result (see below for further discussion).

Alongside these attempts to commodify waste and render it a resource within the Outer Space economy are attempts to render waste provisionally manageable. Mark assured me that asteroid mining waste "is essentially a non problem [sic]" and that his company planned to "bundle" their waste and leave it in the asteroid's current orbital slot. However, this was a notable exception with no existing obligation for companies to do this nor any oversight to enforce this, emphasising Helen's remark on the need for regulation in this area.

[188] Here we may think of Moore's (2012) discussion of waste and how this process spans the waste categories of waste as a non-Marxian commodity and waste as a resource.
[189] Taken from participant observation notes of the *ESPI* conference 2017.

Indeed, Section 12 of the *Artemis Accords* – the section on 'Orbital Debris' – begins to address this issue somewhat, subsections 1 and 2 stating that:

> "1. The Signatories commit to plan for the mitigation of orbital debris, including the safe, timely, and efficient passivation and disposal of spacecraft at the end of their missions, when appropriate, as part of their mission planning process. In the case of cooperative missions, such plans should explicitly include which Signatory has the primary responsibility for the end-of-mission planning and implementation.
>
> 2. The Signatories commit to limit, to the extent practicable, the generation of new, long-lived harmful debris released through normal operations, break-up in operational or post-mission phases, and accidents and conjunctions, by taking appropriate measures such as the selection of safe flight profiles and operational configurations as well as post-mission disposal of space structures."

However, whilst this international accord begins to broach the issue of waste through calling on signatories to '[take] appropriate measures such as . . . post-mission disposal of space structures', this is insufficient at present for two reasons. Firstly, the *Artemis Accord* signatories are nation states, not private companies, and subsection 1 states that it is the signatories' responsibility to ensure the Accords are upheld, allowing private companies to avoid culpability. Secondly, the 'disposal of space structures' does not necessarily apply to asteroid mining waste, mining waste having traditionally been rendered an 'externality' in

terrestrial mining processes (Bridge, 2000). Given this lack of regulatory structure *vis-à-vis* asteroid mining waste, NSE actors were asked where responsibility lay in the case of a collision of accident, to which I was told that there is "No answer yet – answer when it comes to it. If there's a desire to explore and discover, it'll carry on"[190].

Whilst the idea of asteroid mining waste was often met with speculative ideas of how to commodify the discarded material or means to render it provisionally manageable, interviewees and associated materials also responded to this "non problem [sic]" (Mark) by ignoring the potential issues posed by mining discard. If we consider Figure 5.5 in Chapter 5, the conceptual depictions of asteroid mining operations completely omit waste as part of the imagery. Instead, we are presented with a 'clean' image where waste does not exist and the mining process proceeds unproblematically. Indeed, although Gary had suggested that waste material could be used as a propellant[191], he also informed me that there would be no waste from the mining process. Instead, this discarded material would be "a new item to consider with regards to space system architecture". In response to these claims that waste could be used as a propellant or would simply be a new part of the 'space system architecture', the potential scale of asteroid mining waste was raised[192] to demonstrate why this material may be an issue. This point was met with irritation and I was informed that "Thinking of it as waste is just rubbing me [Gary] the wrong way". This response is hardly surprising as increased scrutiny of the potential implications of asteroid mining waste could see regulatory frameworks drawn up and imposed to mitigate and manage this material, representing the

[190] Quote taken from participant observation notes from the *SFF* conference, 2018. The comment was made in response to a question I asked the presenter.
[191] Which would still see mining waste emitted into the wider Outer Space environment.
[192] Using figures discussed in the following subsection.

sort of "overbearing regulatory regime kills off innovation by accident"[193] that private actors were so keen to avoid.

Thus, the issue of asteroid mining waste is being dealt with through a combination of attempting to render it provisionally manageable – whether this be through its commodification or 'containment' – or by ignoring the matter: declaring waste a "non problem [sic]" that simply becomes "a new item to consider with regards to space system architecture". However, the irritation this topic induced in some interviewees means we may wish to scrutinise asteroid mining waste rather than simply dismissing the matter out of hand. It is this issue that I now turn to discuss.

6.3.2 A Trillion Tiny Daggers

Whilst many NSE actors were quick to dismiss asteroid mining waste as a "non issue [sic]" (Mark) with associated concept art omitting waste from its imagery, or responded to queries with irritation – such as Gary's response above – others admitted that the issue needed to be thought through. As Helen, an NSE consultant, said on the matter ". . . the implications of [asteroid mining] could be significant and we may not even realise it at this point . . .". It was suggested that the lack of discussion or analysis on the potential issues of waste was actually due to the time horizons involved in these projects coming to fruition (see James' comment below).

However, my positionality of growing up in a (post)extractive area, coupled with Wales' national history, have taught me to be sceptical of dismissing waste as an issue due to its potential problematic nature being "so far down the road". Whilst mining companies often

[193] Quote taken from participant observation notes of *SFF* conference, 2018.

dump waste into common-property areas to render it an 'externality' to the mining process itself (Bridge, 2000) and seek to manage the politics of time to assuage concerns (Kirsch, 2014), mining history and its present-day 'legacies' abound and encourage me to scrutinise and be sceptical of any claim of waste as a "non issue [sic]". The most infamous instance here is the Aberfan disaster, where numerous concerns were raised about the colliery spoil tip and ignored[194], whilst mining 'legacy' waste has come to the fore in Wales with recent coal slips (nation.cymru, 2020) and flooding (BBC News, 2021). Indeed, following these issues, a study was conducted that found 294 'high-risk' coal tips were present throughout Wales (Fairclough, 2021). With these poignant examples in mind, this subsection takes the material dimensions of asteroid mining seriously, combining data from publicly-accessible databases with the speculative method to begin a conversation around the socio-material issues presented through asteroid mining and its attendant waste.

Before delving into this matter, I wish to echo Valentine's point regarding speculation and Outer Space futurity: that this conversation deals with the implications of my informants' material labour and imaginative talk that should be considered in its own terms because of the insights this can provide us when thinking with and through these issues (2017). Moreover, this speculation allows for the "deep empiricism" discussed in Chapter 4: one concerned not only with isolated and discrete facts but also their relations and focus of togetherness, where the world is always in the making and both the human and other-than-human can be accounted for (James, 2011: Savransky et al., 2017: Whitehead, 1967). With

[194] See https://prruk.org/aberfan-disaster-1966-power-and-corruption-in-the-valley-of-death/ for a good overview.

these points in mind, let us begin thinking through the manifold complexities of taking asteroid mining waste and its implications seriously.

As James noted in our discussion on asteroid mining waste, the main focus when it comes to waste and Outer Space has been on orbital junk:

> "There is a ton of energy today going into junk in earth orbit and several companies and governments spinning up programs to address this, but when it comes to junk as far away as the asteroid belt, that is a problem so far down the road that I do not think much has been done on it."

This focus on orbital debris is understandable given that this issue already exists, having been brought to the fore recently through *Long March 5B*'s uncontrolled re-entry (Rourke, 2021) and popular images of satellite debris, such as the image below. Indeed, it has been noted that a sugar-cube sized piece of space debris has a similar impact force of an exploding hand grenade (Clark, 2012). However, with issues of space waste already existing – coupled with our knowledge of mining waste issues – the lack of discussion on asteroid mining waste needs addressing: this issue being absent not only in discussions on asteroid mining, but in concept art such as that noted in Chapter 5 also. Presently, the only empirical work that considers asteroid mining waste is Fladeland et al.'s (2019) examination of meteoroid stream formation from asteroid mining. Their work looks at some of the potential unintended consequences of asteroid mining: given that the principal focus of asteroid mining efforts is on NEAs, any debris streams created could pass through Earth's orbit and influence meteoroid stream formation.

Whilst this work is timely and provides some interesting material, their work only focuses on the terrestrial implications of asteroid mining waste and does not account for the potential off-world implications these waste streams may pose. With this in mind, I will explore some of the materialities of asteroid mining waste, the size and scale of this waste, and its implications for Outer Space futurity.

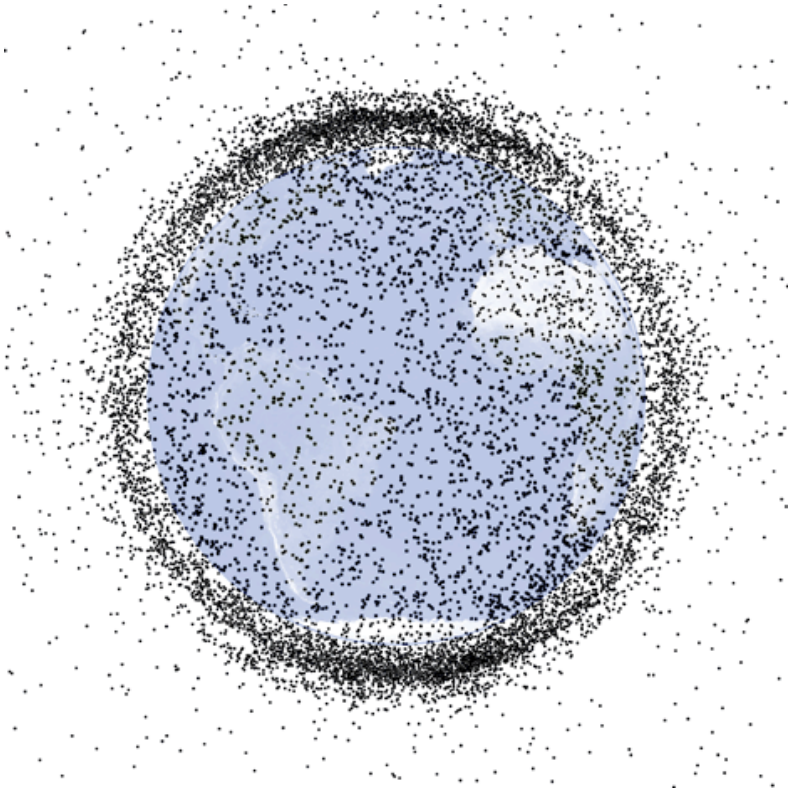

Figure 6.1: An image of human-made satellites currently orbiting Earth, 95% of which is classed as 'space junk'. Image sourced from: https://earthobservatory.nasa.gov/features/OrbitsCatalog

Presently, no information has been produced regarding the *average* size, dimension, and density of asteroids. Instead, data exists pertaining to individual asteroids that range in size. At the upper end of this limit is Ceres: ~965Km in diameter (Williams, 2019) and

containing an estimated 25% of asteroid material in our solar system (Glaze et al., 2019)[195]. Asteroids range in size from Ceres to diameters as small as 0.5Km. Given the lack of data on the average size of an asteroid, I have used information from Williams' (2019) *Asteroid Fact Sheet* to generate data on the volumes of two NEAs that permit a discussion on the material implications of the size and scale of asteroid mining waste. In the ensuing discussion, I have assumed generous yield rates of 90%, resulting in a 10% discard rate.

For the sake of comparison, two NEAs were selected from Williams' *Asteroid Fact Sheet*. The asteroids Geographos and Bennu were chosen as both are classed as NEAs[196] and represent the different sizes of asteroids[197] present within 1.3 AU of Earth – the former being a middling asteroid and the latter a small one. Geographos has an approximate volume of 33.49Km^3, whilst Bennu has an approximate volume of 0.49Km^3. Taking these figures together, an average asteroid volume of 16.99Km^3 is produced. Using this information, if we assume asteroid mining produces a high yield rate of extractable materials and that only 10% of material is discarded in these instances, then Geographos would produce 3.35Km^3 of waste, Bennu 0.05Km^3, and the average would be 1.70Km^3.

Whilst these numbers may appear relatively small given the context of Outer Space, the issue lies not only with the volume alone but with the materialities of this waste. Although some plans for asteroid mining have discussed bringing asteroids into orbit around the Earth, all of the NSE interviewees dismissed this idea, saying that it made more sense to "play the field as it lies" (James) and mine asteroids in their current orbital slots. The proposed method for mining would see asteroids ground down by machinery in its entirety, allowing all minerals

[195] We should note, however, that this percentage decreases over time as new asteroids are discovered.
[196] Within 1.3 AU of Earth.
[197] All calculations are rounded to two decimal places throughout this discussion.

of ‘value’ to be extracted. Indeed, Mark noted that “grinding asteroids is likely inevitable”, though noted his company plans to ‘bundle’ the waste material together after processing. However, this was a notable exception with other NSE actors dismissing the issue, Gary having argued that there would be not waste after mining “[the] leftover material [being] a new item to consider with regards to space system architecture”. Instead, asteroid mining companies and associated actors seem content in leaving trails of waste in the wake of their mining operations.

Although dismissed by NSE respondents (with the exception of Helen) and the resounding silence on the issue throughout the wider literature and published asteroid mining materials, this is an aspect of the asteroid mining process that needs thorough consideration. Whilst the discarded material would be small indeed, the particulate matter would possess a severe angularity created through the ‘grinding’ process. Consequently, the material waste would not be a solid mass but a cloud of particulate matter. This particulate matter would have a jagged angularity after the ‘grinding’ process that would persist throughout its life course due to the lack of erosion in the extraplanetary environment of Outer Space[198]. Consequently, the issue of asteroid mining waste is not necessarily the volume of waste alone but the materiality of this discarded waste. Furthermore, adding to these combined issues of volume and materiality is the speed at which these materials travel, micrometeorites travelling at velocities of >10Km/sec (Hörz et al., 1971). This, combined with both the volume and angularity of asteroid mining discard, would create a dynamic category of waste that

[198] Here we may think back to Chapter 5 and the discussion around *Off World Research*’s issues with machinery and lunar regolith simulants.

would be virtually untraceable for mapping purposes due to the small particulate matter produced, full-sized asteroids frequently 'hiding' from detection themselves[199].

Indeed, to illustrate the scale of this potential issue, we can estimate the quantity of sand-sized particles produced as asteroid mining waste (as opposed to the volume). Using the volumes of the example asteroids above, we can begin to get a sense of this issue. The average size of a particle of sand is approximately $0.56mm^3$.[200] Using the aforementioned volumes after a yield rate of 90% would see Geographos produce ~$5.9x10^{19}$ particles and Bennu produce ~$2.7x10^{17}$ particles in waste material. This would be an average of ~$3.01x10^{19}$ particles produced as mining waste. The scale of waste here only represents two of some 16,000 NEAs[201] and this waste poses potential material and spatio-temporal issues not only for the terrestrial context (as Fladeland et al. (2019) have demonstrated) but for the Outer Space environment more broadly. It is these issues I now turn to consider.

6.3.3 Navigating the Spatio-temporalities of Asteroid Waste

Whilst the potential issues of asteroid mining waste have been tentatively explored through the work of Fladeland et al. (2019), this has focused on the *terrestrial* implications. However, if we attempt to move our thinking beyond the terracentric, then a host of other issues become apparent for the Outer Space economy. Whilst asteroid mining advocates have argued that this project needs to be realised to make a sustained human presence in Outer Space 'sustainable', ignoring waste acts as a contradictory logic that may confound these goals. 'Dirt' in Outer Space already bears the potential to damage or disrupt equipment[202] but

[199] Something asteroids are often accused of doing, see for example Saplakoglu, 2019.
[200] This figure was calculated using the median figures in Price (2000)
[201] Using the average value calculated here, mining 16,000 asteroids would produce ~$4.816x10^{23}$ particles of waste or 4.816 septillion particles.
[202] See Rabie (2021) for a discussion on how 'dirt' is presently affecting space telescopes.

the scale and volume of asteroid mining waste, its materiality, and the sheer quantity of particulate debris would exacerbate this issue even further. Indeed, a key argument in favour of asteroid mining is that it could support off-world systems and decrease the energy and travel times to get to Mars. However, creating unmarked debris fields would undo this objective. If we think back to Mark Clifton's *Eight Keys to Eden*, they note in their fictitious exploration of the solar system that a microsecond-updated map was needed to make Outer Space navigable although the problem could be overcome by flying over or under an asteroid field. Whilst the debris fields of asteroid mining could be overcome in a similar fashion, this would actually see interplanetary travel times *increase*: directly contradicting part of the asteroid mining industry's proposed goals.

Alongside the issue(s) of diminishing interplanetary navigability and actually increasing travel times – contrary to the NSE's goals – are the temporalities of this waste. As previously noted, the inherent nature of the Outer Space environ means there are no erosion processes present as there are on Earth. Consequently, asteroid mining waste can become a mode of 'slow violence' whereby the ramifications of its presence may "stretch beyond the horizon of imaginable time" (Nixon, 2011; p.47). The spatio-temporalities of this waste's slow violence pose narrative challenges due to the difficulty of communicating its temporal duration combined with the difficulty of narrating its physical scale (ibid; p.216). This issue of conceiving of and communicating the spatio-temporalities of Outer Space was noted by James when he said "Even in the solar system, days, weeks, months . . . we haven't got yet to know [sic] how big the solar system is". They continued this line of thought with:

> "What does the economy look like when you get to that scale? It'll be so different in terms of size and scale – how much we can spread out – space, and time, and distance are going to become things that . . . these are going to become issues that are very difficult to conceive of right now."

Here, James notes the inherent complexity of trying to think beyond the terracentric, of the sheer scale and difficulty of dealing with the Outer Space environment. Indeed, the complexity noted by James indicates a key issue of the potentialities of asteroid mining waste: its unknowability. This unknowability coupled with its unbounded nature produces a dynamic waste that may have no timeframe, eliding typical narration or description, thereby producing issues for both the spatialities and temporalities of Outer Space that go far beyond the horizon of both imaginable times and spaces (Erikson, 1994: Nixon, 2011). With the problematic nature of asteroid mining waste in mind, we may think back to Helen's remarks here, that ". . . the implications of [asteroid mining] could be significant and we may not even realise it at this point . . .". Helen's remark, whilst made during an interview prior to the scale of waste being calculated, is incredibly salient and poses a serious provocation for the asteroid mining industry that is, as yet, ignored or unanswered[203].

6.4 Destabilising the 'Final Frontier' Through Waste

Along with asteroid mining waste manifesting a new mode of 'slow violence' (Nixon, 2011) that disrupts the navigability of Outer Space, and operating in contradiction to the purported logics underpinning part of the industry's arguments of reducing interplanetary travel times

[203] As discussed in previous sections.

and costs, waste also exposes the issues of the 'frontier' narrative advanced by private actors. Thinking with and through the potentialities of asteroid mining wastes allows us to decentre capitalism, Eurocentrism, and terracentrism further. Specifically, waste poses a contradiction for the capital accumulation of extraction: increasing the costs of extraction (should the waste be dealt with) that sees these materials emitted into common-pool areas to mitigate their costs through making them an 'externality' to the mining process (Bridge, 2000). However, this waste bears the potential to increase interplanetary travel times and associated costs through spacecraft having to avoid certain orbital slots, working against purported aims of asteroid mining: to "industrializ[e] the frontier"[204]. Moreover, the 'tradition of resource extraction' has distinct connotations with colonialism, with waste being a specific symptom of the processes involved in this (Broughton, 2013: Moore, 2012: Wilkes and Hird, 2019). Indeed, the 'frontier' narrative coupled with the attitudes towards waste serve to highlight the Eurocentric outlook to both the histories of 'frontierism' and the legacies of waste more broadly. Waste confounds the normative capitalistic and Eurocentric discourses of the frontier through representing a particular geosocial formation that will need to be dealt with (Hird, n.d.: 2015): one that destabilises the frontier narratives supported and (re)created through the discourses discussed at the outset of this chapter.

This chapter has looked at the processes underway that aim to enclose Outer Space. Specifically, it has looked at how this is being advanced through multiple sites and by multiple actors. It has done this through looking at the various legislations that are being drawn up and (re)shaped through the lobbying efforts of private actors. These legislations are beginning to construct a rights regime for Outer Space that renders asteroid mining permissible and Outer

[204] Information retrieved from analysed website material (DSI (2017), 'Who We Are'. This webpage is no longer accessible).

Space provisionally navigable. It has then discussed some of the public-private discourses that are being perpetuated to advance arguments for enclosure: whether this is through arguments of utility value and economic 'waste' or through the supposed 'green imperative' behind asteroid mining. Following this, the chapter shifted focus to consider matters of material waste, an inherent part of any extractive frontier (Bridge, 2000: Mumford, 1934: Reno, 2015): the 'frontier' operating as a site of invisibility in this instance. The latter parts of this chapter interrogated some of the 'invisible' processes at play in this 'frontier', going on to discuss the spatio-temporal issues posed by asteroid mining waste and how this destabilises the 'frontier' narrative, contradicting the industry's claims. However, the 'frontier' discourses are not the sole preserve of private actors but are challenged, confounded, and reconstituted through the works of Ethnofuturists. It is these actors and their rewriting of the 'frontier' narrative that the following chapter turns to discuss.

Chapter 7: Another Space

7.1 Introduction

The preceding discussion chapters have focused on how outer space is being (re)cast as a frontier for private enterprises: being 'opened' and 'enclosed' through various machinations that mobilise a combination of policy documents[205], NSE press releases, lobbying attempts, and public and private discourses that already refer to outer space as a 'frontier'. These methods culminate in a discourse that translates data pertaining to asteroids into a fiscal value through an asteroid's materiality becoming 'knowable' and, consequently, commodifiable. However, whilst this discourse stresses how the 'value' posed by asteroids can be used as an argument for the commodification and subsequent privatisation of outer space, it also elides the issues posed by an asteroid's material waste. These risks are either omitted from discussion or downplayed through a variety of counterarguments, chief amongst which is the perversion of the common heritage principle. The co-option of the common heritage principle posits that future generations will benefit from common pool resources through 'freeing' the materials for use in markets that will 'trickle down' through the generations.

Whilst the present discussion has focused on the important themes within the asteroid mining story, thus far the focus has primarily been upon the discourses created within – and perpetuated by – asteroid mining companies and associated NSE actors. The conferences attended, along with information collected on asteroid mining companies' board members, were all majority (if not solely) white in their composition. Through engaging with this, the conversation has necessarily engaged with an Ethnofuturism that is implicitly and

[205] Informed, to varying degrees, through lobbying by numerous NSE companies (a claim made by NSE actors during participant observation, several interviews, and reported in news reports collected as some of the grey literature).

explicitly informed by and through invisible whiteness, an issue present within much 'popular' Science Fiction and subsequent 'fandoms' (Redmond, 2016: Woo, 2017). The discourses therein are inescapably constructed from that positioning and through a EuroAmerican-centric rubric. Having considered asteroid mining as expressed through EuroAmerican onto-epistemological frameworks[206], this chapter turns attention to Ethnofuturisms that draw upon non-EuroAmerican discourses and histories: turning to Ethnofuturism also enables a conversation to be opened up with non-White imaginaries that attending NSE events precluded. Instead, this chapter turns its focus to an engagement with Ethnofuturisms that are different to the EuroAmerican discourse encountered thus far.

The chapter begins by exploring how Ethnofuturist works can operate as a source of counternarratives that are juxtaposed to the normative assumptions inherent within the popular EuroAmerican imaginary and its associated discourse. The chapter moves on from this section to look at the inclusionary and exclusionary practices involved in Ethnofuturisms, troubling the normative discourses that have been implicit throughout the imaginaries and arguments espoused by NSE actors in the preceding chapters. The proceeding subsections will consider spiritual relations with extraterrestrial resources and how these 'alternative' ontologies challenge typical conceptions of 'Outer Space' and how this not only challenges the normative spatial delineations of Outer Space but engages with and through a 'temporality of alterity'. Throughout the proceeding discussion it is important to note that these views – EuroAmerican and otherwise – do not exist in a simple binary, there being a range of perspectives within and between the groups interviewed in this research. Indeed, just as I am using 'EuroAmerican' in a particular way during this chapter, it should also be

[206] When using the term 'EuroAmerican', I am referring to a framework premised upon settler colonialism and the subtending Judeo-Christian ideology (noted during Chapter 1 and returned to later).

noted that I am using 'Ethnofuturism' in a particular manner too. I have previously noted that the term blends the 'archaic' with the 'futuristic' (Hennoste, 2012: Kolcheva, 2015), meaning there are a range of 'white' Ethnofuturisms at play (here we may think of Cambrofuturism, or the futurisms of the Basque and Catalan territories as examples). However, for the purposes of this chapter, I will be using 'Ethnofuturism' to generally mean those future imaginaries discussed and (re)created by peoples and groups that break away from a reliance on a 'Grand Historical Narrative' and do not readily fit into the category of 'EuroAmerican' as defined above.

7.2 Projections, (Counter)Narratives, and Inclusionary/Exclusionary Practices

Various commentators have referred to Outer Space being little more than a giant void or a vast emptiness[207]. This conception of Outer Space was advanced by multiple NSE interviewees, one regarding Outer Space as just "dead rocks" and others arguing that Outer Space's vast emptiness made issues of material waste irrelevant and inconsequential[208]. However, this position fails to fully account for a series of material and immaterial processes that already operate within and upon Outer Space. In a material sense, Outer Space already has waste strewn throughout it, discarded rovers and satellites deteriorating on several planets and there being sufficient orbital debris surrounding Earth that physical and economic manifestations of Kessler Syndrome[209] have been widely discussed (Adilov et al., 2018: Kessler

[207] Indeed, Outer Space was regarded as a complete vacuum until as recently as the 1960s. Parker (1958) published the first paper mathematically proving the existence of solar winds, discounting the idea that Outer Space was a vacuum. However, the paper was rejected four times and, once published, the scientific community rejected the idea. This was the case until *Mariner 2* was launched in 1962 and made several readings en route to Venus, confirming Parker's models. In 2018 the *Parker Solar Probe* was named after Eugene Parker – the first to be named after a living scientist.

[208] This position was forwarded by several interviewees and during personal correspondence with an asteroid mining company.

[209] A process whereby the build up of debris increases the potential for collisions, resulting in the creation of further debris. The physical aspect applies to the volume of material that would lead to this occurring, whereas the economic dimension relates to the profitability of orbits.

and Cour-Palais, 1978: Kessler et al., 2010). Perhaps more pertinent than the material dimension belying Outer Space's 'emptiness' are the immaterial processes by and through which a myriad of socio-material relations are (re)created. Far from being a vast void, Outer Space is full of ideologies that have been projected upon it by a range of actors with different interests and frameworks (Valentine, 2012). Indeed, this was noted by Arendt shortly after the launch of *Sputnik* in her book *The Human Condition* (1958) wherein she argued that Outer Space is imbued with moral and philosophical hopes, dreams, and deliberations. Instead of an emptiness, Outer Space is 'fully laden with cosmic dreaming, theological wonderings, and science fiction fabulations' (Kearnes and van Dooren, 2017; p.179). It is arguably here that the most important debates are to be had as the frameworks created, adopted, and brought to bear upon Outer Space will invariably influence and shape the socio-political-material relations that develop therein. The relations (re)created through these processes will, in various ways, inform attitudes towards Outer Space and its associated materials, infrastructures, and regulations, to name a few areas. Consequently, the narratives produced and their associated onto-epistemological frameworks take on a significance beyond mere 'storytelling'. It is these (counter)narratives I now turn to discuss, starting with the futures (re)produced through a EuroAmerican-centric rubric before turning to consider ideas that are being advanced by and through the work(s) of Ethnofuturists.

7.2.1 The Stories So Far

"The pioneering spirit has always defined America and we're picking that up in many other fields . . .

After braving the vast unknown and discovering the New World, our forefathers did not only merely sail home . . . in some cases never to return. They stayed, they explored, they built, they guided and, through that pioneering spirit, they imagined all of the possibilities that few dared to dream. Today the same spirit beckons us to begin new

journeys of exploration and discovery, to lift our eyes all the way up to the heavens and to once again imagine the possibilities waiting in those big, beautiful stars if we dare to dream big . . .

This is a giant step toward that inspiring future and toward reclaiming America's proud destiny in Space . . ."

-Donald J. Trump[210]

Outer Space imaginaries have been (re)structured through a hegemonic EuroAmerican onto-epistemological framework. This dominant narrative assists in perpetuating a EuroAmerican futurity through a process of disimagination (Giroux, 2014). The process of disimagination selectively edits the historical narrative, removing certain voices, modes of resistance, and alternative accounts, curtailing the ability to imagine futures outside of a EuroAmerican ordering, eroding the capacity to ideologically shift. It is through the processes of disimagination that the condition of capitalist realism is enabled – a state of affairs wherein it is easier to imagine the end of the world than the end of capitalism (Fisher, 2009). Consequently, this framework – informed by a discourse that draws upon a white, ethnocentric history – implicitly and explicitly draws upon familiar tropes of white settler colonialism, such as enclosure, working land to produce 'value', and the displacing of indigenous/non-Western systems and frameworks (Bhabha and Comaroff, 2002: Hesse, 2002: Loomba et al., 2005: Parry, 2002: Wilkes and Hird, 2019: Wood,2017: Young, 2001). Indeed, this Ethnocentric discourse not only operates to project the dominant values of the 'West' upon Outer Space, but also assists in the project or formation of 'the West' itself (Hall, 1992:

[210] Parts of Donald J. Trump's speech when announcing the Executive Order to re-establish the National Space Council and NASA's Artemis programme, 30th June 2017 (edited for clarity).

Hesse, 2002)[211]. This totalising narrative culminates in the exclusion and silencing of any voices that exist contrary to the EuroAmerican imaginary and world-ordering that ensues. This results in what can be regarded as a hegemonic structuring of Outer Space and subsequent relational frameworks.

The EuroAmerican-centric rubric through which understandings of Outer Space are structured, informed, and (re)imagined, demonstrate that the frontierism of white settler colonialism is perpetuated rather than diverged from. As one NSE consultant remarked whist being interviewed: "The frontier hit the West Coast and went up". This comment – made in reference to what they regarded as the continuation of the 'American Story' – is telling of the broader context within which asteroid mining and other off-world extractive industries are set to take place. Although frontiers can be regarded as a material reality, the ideological undercurrents that drive engagements with these areas inevitably inform the socio-material relations that take shape (Redclift, 2006). The sentiment expressed in the above statement is commonplace amongst U.S. Outer Space discourse, various speakers at conferences frequently drawing upon notions of the 'American Frontier', manifest destiny, and the

[211] This assertion arises through the (re)creation of the 'Other' through which to make sense of itself to some degree (Barnett, 2012: Bhabha, 2004: Bush, 2006: Cloke, 2005: Gandhi, 1998: LeVine and Campbell, 1972: Loomba, 2005: McLeod, 2010). However, this contribution to the continuing project of 'the West' is also fuelled through conceptualisations of the 'future' that are linked to State security and the perpetuation of the geopolitical hegemony of 'Western' powers. Specifically, this need to recreate and anticipate future changes is spurred on (predominantly) through US (inter)national policy (discussed extensively through sections of the conferences attended for participant observation). This need to (re)imagine Outer Space futures as part of the US national strategy is predicated upon a history of national existential crises within the US vis-à-vis Outer Space and foreign powers. Despite popular narratives, the US was beaten to numerous landmarks during the Space race. The lasting impact of this legacy shows in much US space policy. This history has led to a present condition wherein numerous nations with varying Outer Space agendas have become conceived of as a 'threat' by the US. This current set of affairs has its roots in 3 areas: 1) Outer Space is crucial to the US military-industrial complex; 2) Certain Space Powers (e.g. China) have national programmes with ideological underpinnings to be construed as sufficiently different to the US's fear of an unknown 'other' to kick in, and; 3) The numerous defeats suffered by the US during the Cold War (conveniently brushed aside in the 'Grand Narrative') leads to any substantive action by any power outside of the US being construed as some loss or threat to its hegemonic power and, ultimately, instigates a series of moral and ideological panics as historical defeats and any rivalry of power have frequently come as a shock to the US.

'pioneering spirit'. Indeed, the excerpt at the beginning of this subsection – taken from Donald J. Trump's announcement of the Executive Order for the Artemis Programme[212] – is strewn with references to EuroAmerican[213] frontierism. Invoking terminology such as 'the pioneering spirit', 'braving the vast unknown', and 'new journeys of exploration and discovery' all give a clear indication of which version of America's history is being drawn upon, perpetuating an Ethnocentric futurism, curtailing counternarrative futurisms, and contributing to the disimagination of extraterrestrial futures.

The NSE consultant's above comment does not only allude to the moral and philosophical projections Arendt (1958) spoke of but informs us of the type of frontierism being utilised when framing Outer Space and asteroids as such. This conceptualisation of the 'frontier' not only informs the way Outer Space and its accompanying materialities are related to and engaged with, but also produces a totalising conceptualisation of 'humanity' and human-nature relations. Through drawing upon the history of the American Frontier, the ideological basis through which Outer Space is rendered 'knowable'[214] and the socio-material relations that are subsequently created may be better understood. It is this framework that allows Outer Space and objects within it to become nothing more than a medley of 'dead rocks', as the CFO of a space launch company informed me. Moreover, this lack of life was combined with a framing that attempted to make asteroid mining appear ethical through reference to past colonialism, James telling me that they:

[212] Announced in 2017. The programme aims to take people back to the Moon by 2024.
[213] I use 'EuroAmerican' rather than simply 'American' here as the processes of frontierism began with the European encroachment upon – and invasion of – indigenous peoples' lands that was later continued by 'Americans' following Independence. To have simply used the term 'American' here would have been to implicitly remove European culpability in the process.
[214] We can think back to Chapter 5 here and reread the processes through which asteroids are made 'knowable' with questions of how this is done and to whom these data are then conveyed, through what means, and to what ends.

> "run into [the colonial question] in a bunch of places; there is a . . . it's good to look on past development – whether that was colonialism or whatever – and recognise . . . there's nothing wrong with understanding and owning the sins of the past: that's a good activity, it's a good thing to do. But, it can lead to thinking where you paralyse yourself and say we can't do anything. At its worst, it actually does this weird twist thing whereof 'well, humans are somehow bad and so we should not do this or that' . . . we're looking for the first time at an environment that is filled with resources and devoid of life".

This conception of Outer Space was not only espoused by NSE interviewees but is reinforced via materials produced by asteroid mining companies. Asteroid mining companies have framed their activities as a set of 'Missions to Industrialize the Frontier'[215]. To 'industrialize the frontier' effectively, companies need to render asteroids and their materialities 'knowable' whilst controlling the discourses surrounding the generation and consumption of this data. This control is exercised through the removal of certain topics (e.g. how much of an asteroid would become waste and what would happen with that material). Whilst controlling the discourses of data, asteroid mining companies' desire to 'industrialize the frontier' taps into an idea of what the 'frontier' is. Alongside the term's ability to conceptually 'open' Outer Space – both ideologically and physically – it also evokes a particular history viewed from one side of events. Akin to how the 'frontier hit the West Coast and went up', the use of 'frontier' in asteroid mining companies' public communications are designed to evoke nineteenth century frontierism and the various 'gold rushes' of the time

[215] Information retrieved from analysed website material (DSI (2017), 'Deep Space Missions: Delivering resources to open the space economy'. This webpage is no longer accessible).

(Braudel, 1982: Lynch, 2002: Mumford, 1934: Nef, 1964)[216].Through drawing upon this history, a particular set of human-nature relations are evoked once more, being both implicitly and explicitly bound up in this rendition of frontierism.

With these points in mind, the EuroAmerican discourse that encourages and perpetuates the frontier narrative of Outer Space also extends the Judeo-Christian ideology bound up within this articulation of frontierism. As Gary – the NASA contact for NSE SMEs – discussed in his talk at the *SFF* conference, we should "think of the middle ages and cathedral building. Stone masons would work their whole lives and never see it complete but were happy to do it. It's the same in this industry – people are happy to push that boulder further up the hill. It's our destiny". Not only does Gary's remark allude to the concept of manifest destiny, it also speaks to the religious ideals engrained within this particular conception of Outer Space futurity, the aerospace sector being likened to cathedrals and calling for a certain level of sacrifice to the idea, to spend a lifetime working on something that may never be seen. Thus, just as the Anthropocene may be regarded as a geological rendering of the Judeo-Christian ideology (Hird, 2016: 2017a: 2017b: Wilkes and Hird, 2019), so too could this be said of asteroid mining and all extraterrestrial extraction. This contention is proposed due to the normative discourses surrounding asteroid mining and associated projects utilising – implicitly and explicitly – a EuroAmerican onto-epistemological framework that is informed by, and perpetuates, a Judeo-Christian ideology. In particular, when discussing extraterrestrial extraction this ideological framing mobilises several core characteristics of colonisation – land grabbing (or enclosure), working land to create 'value', and displacing indigenous (or non-

[216] Indeed, asteroid mining has frequently been referred to as the 'next gold rush' in media coverage (see Cofield, 2016 and Pandya, 2019 for examples)

Western[217]) systems/onto-epistemological frameworks (Bhabha and Comaroff, 2002: Bush, 2006: Hesse, 2002: Wilkes and Hird, 2019: Wood, 2017). However, the Anthropocene and asteroid mining diverge in their relation to the Judeo-Christian ideology/legacy[218]. Whilst the Anthropocene arguably 'marks a geologic, cultural and political "afterword" to the Christian story' (Wilkes and Hird, 2019) through the exhausting of the planet, creating a futurity through depletion and waste (Hird, n.d.), asteroid mining may instead be regarded as a perpetuation of this story rather than an "afterword". Asteroid mining operates as a perpetuation of this ideology through the recasting of EuroAmerican frontierism into and upon Outer Space[219], maintaining hegemonic structures and perpetuating a process of socio-cultural 'disimagnination' *vis-à-vis* extraterrestrial extractivism. These EuroAmerican futures have key tenets of the Judeo-Christian ideology bound up within them, akin to the 'frontierism' of history. However, despite the seeming dominance of this futurism, there are various counternarratives that challenge these renderings of the future. It is these contrasting Ethnofuturisms that I now turn to discuss.

7.2.2 Ethnofuturism: Challenging Structural Whiteness and the Future(s) of Outer Space

Through basing extraterrestrial socio-political-material relations upon imaginaries that take the EuroAmerican onto-epistemological framework as a normative position a series of inclusionary/exclusionary boundaries are formed and perpetuated beyond (and including) those pertaining to enclosure. These additional boundaries are created around ethnic identities, (re)creating discourses of *who* belongs within conceptions of the 'humanity' that is

[217] Although I have used the terms 'indigenous' and 'non-Western', I do not intend to create a set of binary positions here (as mentioned at the start of this chapter). Instead, these terms should be read as systems and frameworks that do not fall into the prevailing EuroAmerican framework.
[218] This ideology was briefly noted in the introduction, explaining how this is premised upon claiming land *for* God wherein it is subdued and subsequently utilized (Wilkes and Hird, 2019)
[219] Arendt's (1958) ideas of 'projecting' ideas upon Outer Space are particularly relevant here.

set to inherit – and inhabit – Outer Space. Indeed, the fallacy of Outer Space belonging to all [hu]mankind[220] was noted by the CEO of a cubesat launch company, who, when addressing the audience in their talk, began with: "Does space belong to everyone? No. It should, but it doesn't"[221]. Although the speaker went on to use this as a gateway into discussing issues around technological capabilities and the practicalities of getting into Outer Space, the statement also acts as a poignant remark on the politics surrounding discourses of Outer Space, uttered in a conference of majority white attendees and all European and American.

However, the hegemonic imaginary of EuroAmerican futurism is disrupted and contested through various Ethnofuturistic writings and artwork[222]. If we understand Ethnofuturism at its most basic level – an imaginative process that engages the *Ethno-* (referring to the archaic, indigenous, or cultural histories of peoples) and *-futurism* (deemed as the cosmopolitan, urban, and contemporary/future) (Hennoste, 2012) – and accept that texts are not neutral but socio-political artifacts (Aitken, 1997: 2005: Driver, 2005: Kitchin and Kneale, 2001: 2002: Fairclough, 1992: 2001), then we can look upon Ethnofuturist works that draw upon non-Western histories and cultural specificities as sites wherein the hegemony of the EuroAmerican onto-epistemological framework is agitated, contested, and refuted. Indeed, the ability of Ethnofuturist work that draws upon socio-cultural histories other than the EuroAmerican 'Grand Narrative'[223] is described by Nalo Hopkinson in their introduction

[220] Written as such due to this speaking towards the *Outer Space Treaty*'s most famous commitment, though edited to read as 'humankind' rather than the original 'mankind'.
[221] Quote taken from participant observation.
[222] Here I take 'artwork' to mean not just the production of images, but all of the 'arts' – writing, imagery, sculpture, and so on.
[223] A reminder that 'EuroAmerican' in the context of this work refers broadly to the processes of settler colonialism and that the 'Grand Narrative' I mention here refers to the narrative that describes one totalising view of history. This view largely ignores historical specificities or pluralities and contributes to the process(es) of socio-political disimagination detailed above.

to the short story collection *So Long Been Dreaming: Postcolonial Science Fiction & Fantasy*. Hopkinson succinctly relays that:

> "Arguably, one of the most familiar memes of science fiction is that of going to foreign countries and colonizing the natives, and as I've said elsewhere, for many of us, that's not a thrilling adventure story; it's non-fiction, and we are on the wrong side of the strange-looking ship that appears out of nowhere." (2011; pp.7)

Immediately, Hopkinson draws our attention to the common tropes of SF and the way(s) this draws upon and perpetuates a narrow, singular rendition of history. This does not simply advance the disimagination process (Giroux, 2014) but, within and through this process, operates as a platform whereby inclusionary and exclusionary boundaries are (re)created and strengthened. Discourses are perpetuated and histories normalised, forming ideas of which 'humanity's' history matters and, consequently, what qualifies to inform ideas of futurity through the variegated field of Ethnofuturism. Moreover, the ability of different Ethnofuturisms to disrupt the normative 'Grand Narrative' history informing the invisible whiteness of Science Fiction futurity was noted by Janet, an American-Indian Ethnofuturist novelist and short story writer:

> "we've seen in the last few years some serious resistance from some people in the SFF[224] community as minorities became visible on the final ballots of major awards. I found it sad that in an area writing about the future, some group of people unwilling to see the future would have to include all kinds of people, not just white. I'm not saying it is the way of most of the SFF community, because it isn't, but even for a small group to make themselves known just made me shake my head . . . We can see this even in our political atmosphere right now. This bounce back from what looked like a country moving forward to be inclusive and compassionate. Change isn't a straight line, but I believe it's inevitable. Humans react against change when they feel they will lose something, but lose [sic] is also inevitable. The fight to keep things an old way can't win in the long term, even if that long terms takes generations . . . This is reflected in all levels of society, the space industry included."

Indeed, through challenging the dominant historical narrative, so too is the underlying EuroAmerican onto-epistemological framework that operates as a platform from which claims to the future and justifications for subsequent projects are made. In conjunction with works such as those featured in *So Long Been Dreaming*, the Korean-American author Yoon Ha Lee's *a vector alphabet for interstellar travel* provides an engagement with the various rationales behind Outer Space activity. Through this short story, Lee (2013) explores the different 'stardrives' for interstellar travel. Reading 'stardrives' as an allegory for the different

[224] Here SFF stands for 'Science Fiction and Fantasy' as opposed to 'Space Frontier Foundation', as has been the case prior to this instance.

impetuses for interstellar travel, we are introduced to a variety of approaches, including a reference to the present neoliberal approach to Outer Space. This approach is referred to as 'The Profit Motive' and notes the multiplicity of ways actors seek to achieve this end whilst maintaining a broad consensus that this is the correct approach to Outer Space:

> ". . . sages devote a great deal of time attempting to justify the profit motive in view of conservation laws. Most of them converge comfortably on the position that profit is the civilized [sic] response to entropy. The traders themselves vary, as you might expect, in the rapacity of their bargains. But then, as they often say, value is contextual[225]." (Lee, 2013; p.249)

This passage goes beyond simply speaking to the neoliberal conception of Outer Space. Through invoking the idea that 'profit is the civilized [sic] response to entropy', 'The Profit Motive' draws us to the relationship between the 'civilising mission' inherent within much of European colonialism (Bush, 2006: McLeod, 2010), Eurocentric ideas of 'development' (Knox and Agnew, 1994: MacKinnon and Cumbers, 2011), and the Eurocentric approach to history and the subsequent framework(s) dominating the geo- and astropolitics of asteroid mining[226]

[225] The idea of value being contextual has been discussed in Chapter 5, most notably in discussions of how water is being (re)framed and its value restructured through being in the context of Outer Space. Indeed, this contextual value of water is explored in devorah major's *Trade Winds* in *So Long Been Dreaming*.

[226] Indeed, engaging in a closer reading of this excerpt, we can easily read the response to 'entropy' as an invocation of mining (an extractive process that increases entropy that is also self-cannibalising. The 'sages' could be read as economic advisers and political madarins who seek to lobby or justify (non-)governmental responses to conservation laws that hamper their plans for these resources. The reference to grappling with conservation laws is particularly salient at present as the Trump administration has not only attacked various conservation laws on Earth, but has recently announced that the US no longer regards Outer Space as a global commons following the *Executive Order on Encouraging International Support for the Recovery and Use of Space Resources* (6th April 2020).

(Bhabha and Comaroff, 2002: Hall, 1992: Hesse, 2002: Loomba et al., 2005: Parry, 2002: Wilkes and Hird, 2019: Wood,2017: Young, 2001). Lee continues to critique the normalised approach to the historical 'Grand Narrative' and the violences associated with the frontierism predicated upon the Judeo-Christian ideology (Wilkes and Hird, 2019) in the section 'One Final Constant': "Then there are the civilizations [sic] that invent keener and more nimble stardrives solely to further their wars, but that's an old story and you already know how it ends" (2013; p.251). This line is the entire section and neatly conveys the seeming mundanity of the EuroAmerican-centric discourses, so familiar that we 'already know how it ends', echoing Hopkinson's remark on the EuroAmerican discourse having become a 'familiar meme'.

However, Lee also discusses other 'stardrives' or approaches to Outer Space that are not predicated upon the neoliberal EuroAmerican imaginary that is so often evoked. They outline 'stardrives' such as exploration (the Iothal creating vast libraries chronicling the cosmos) or the view that the people colonising the cosmos are akin to a 'disease' (the view of Mrithaya's people). Indeed, despite not necessarily being grounded in an entirely different Ethnofuturism, the incorporation of different rationales for space projects also disrupts the usual EuroAmerican futurity that is frequently couched in neoliberal terminology and practices[227]. The use of these different approaches reminds us that despite the process of socio-cultural disimagination, the neoliberal agenda that is increasingly advanced in both the NSE sector and government circles, even the EuroAmerican imaginary is contested within itself. These themes have been regularly discussed within policy and scientific arenas. Arguments against the privatisation of Outer Space have been voiced in debates around

[227] See previous chapters for context on privatising Outer Space and below where Valentine's (2012) work is engaged and brought into conversation with processes operating in the NSE.

whether the cosmos should be regarded as *terra communis*, *terra nullius*, or a planetary/cosmic park system (Cockell and Horneck, 2004: Collis and Graham, 2013) and the 'disease' of spacefaring species and its attendant biopolitics have been frequently voiced in discussions of biocontamination of other planets and celestial bodies (Bharmal, 2018: Helmreich, 2009: Phillips and Hoffman, 1960: Robinson, 2005: Spennemann, 2004).

Through creating and telling SF stories that centre upon histories and experiences that lie 'outside' of the EuroAmerican 'Grand Narrative', the ethnocentric nature inherent within the 'familiar memes of science fiction' become apparent. These different Ethnofuturisms disrupt 'traditional' narratives of Outer Space projects and imaginaries through challenging the normative discourses that the EuroAmerican imaginary is often predicated upon – even pointing to some of the tensions that lie within the EuroAmerican discourse itself. These Ethnofuturist works not only disrupt the hegemonic EuroAmerican imaginary and the inclusionary/exclusionary logics this perpetuates. Rather than simply claiming space within the future for cultures and peoples 'outside'[228] of the EuroAmerican ethnic, Ethnofuturist works can claim space and bear meaning in the present also. Sarah, a Filipina-American Ethnofuturist novelist, poet, and short story writer who has worked with indigenous communities noted that "What's hidden from you also impacts your identity formation . . . and the reclaimation of an authentic identity, I believe, has to do with putting all of those pieces back together again . . .". This remark encapsulates the importance of Ethnofuturist works. These materials challenge the processes of socio-political disimagination, inclusionary/exclusionary boundary formation, and the hegemony of the EuroAmerican imaginary via multiple fronts. Ethnofuturist SF does not only work to claim a space within

[228] Placed in quotes here due to the baggage of this terminology and the complexity of trying to convey meaning succinctly without perpetuating colonial binaries of the inside-outside/inclusion-exclsuion.

future imaginaries, but also undertakes significant work in claiming space within the historical narrative, these two aspects (that comprise 'Ethnofuturism') bear salience in the present also. Through 'putting all of those pieces back together again', Ethnofuturism challenges the EuroAmerican-centric rubric and allows for identities to be reclaimed, rearticulated, and celebrated once more, operating as a grounds of resistance to an ethnocentric, 'whitewashed' past, present, and future.

7.2.3 'We Let the Neanderthals Die Out': Racialising the Cosmos

As previously noted, asteroid mining and similar projects have been frequently framed as modes of 'opening' Outer Space to human exploration and settlement that operates in the interests of 'all [hu]mankind'. These discourses often deploy the term 'humanity' or 'humankind', negating to mention what this 'humanity' is, looks like, or who it is comprised of. Ethnofuturist works have done much to challenge and disrupt these normative assumptions through drawing upon socio-cultural histories that do not adhere to the dominant EuroAmerican 'Grand Narrative', onto-epistemological frameworks, and renditions of the future (Bould, 2007: Dery, 1993: Hennoste, 2012: Kolcheva, 2015: LeVine and Campbell, 1972: Nelson, 2002). Indeed, the hegemonic discourses of Outer Space and its attendant ethnocentrism were noted by Betty, a Jamaican Afrofuturist novelist and poet through reference to historical allegory:

> "Historically, any time new territories are "discovered" or explored, the dominating culture tends to render any opportunities for marginalized people few and far between. Columbus coming to America. Cortez's exploration of the Americas. We can go on and on."

This interviewee's comment reinforces a salient point: Outer Space and the imaginaries (re)created around and within this do not stem from a vacuum but are conceived of in the present. Consequently, normative assumptions are frequently projected upon Outer Space and extraterrestrial objects (Arendt, 1958: Kearnes and van Dooren, 2017: Valentine, 2012: 2017) and the values of the dominating culture supersede and dictate how these areas are engaged and made sense of.

Indeed, this process does not only project value systems upon Outer Space but exports inclusionary/exclusionary practices and structures with it. Whilst some advocate that Outer Space is devoid of social issues – implicitly implied through the uncritical adoption of the term 'humanity' and advanced by various groups (Vergès, 2017) – this is exposed as a falsehood when we look upon the contested and fractious history of Outer Space. Noting how Outer Space can be a site wherein existing inclusionary/exclusionary boundaries are reinforced and perpetuated, many Ethnofuturist texts[229] and interviewees' actively draw attention to the racialisation of Outer Space and related discourses. As Betty noted of the issue:

> "When some racist white people see non-white folks suddenly populating some scifi empire or universe, they feel encroached on. It doesn't occur to them that the world is full of people of different races; all they think is that people are being political and pushy and bringing politics to their art. Non-racist white folks don't

[229] Due to the constraints of the thesis, I will not be engaging with textual analysis in this section. For some examples of SF that has done fantastic work engaging issues of race and Outer Space, see stories such as Nisi Shawl's *Deep End*, Andrea Hairston's *Griots of the Galaxy*, and Suzette Mayr's *Toot Sweet Matricia* (all in the collection *So Long Been Dreaming*).

care about that. Seeing something different in popular art delights or enlightens them because they are not at war with non-whites."

This point speaks to Ethnofuturism's ability to disrupt and challenge the normative imaginaries that are 'familiar meme[s] of science fiction' (Hopkinson, 2011; p.7), confronting the invisible whiteness noted at the outset of this chapter and rebutting the racialised tropes (re)created through the 'Grand Historical Narrative'[230].

Indeed, although some people regard the depiction of non-White characters within SF and discussions of Outer Space as 'being political and pushy' the need to challenge and tackle structural racism became abundantly clear during one of my interviews with an NSE consultant[231]. The interview began like any other. The topic was introduced, the ethical protocols rehashed, consent forms signed, and reassurances of anonymisation and an interviewee's ability to withdraw from the research at any stage reiterated. The interview began and proceeded like many others, though it was at times a little stilted. When the idea of decolonising Outer Space discourse and engaging different cultures was introduced, the interviewee shrugged and asked "why should I care because I don't . . . We see [Outer Space] and we dream and we hope for a better tomorrow . . . but hope is dangerous. Hope definitely helps to bring human civilisation forward but I also care about my culture . . . my people . . . and I want them to succeed over other cultures". Though feeling awkward, I pressed the interviewee for a more detailed answer. They responded that they did not see why they had

[230] Indeed, in some instances this may be at best – given the rise of the Far Right/'alt-Right' in recent years, racist rhetoric has come out into the open once more, no longer occupying the fringes of society but being encouraged by populist leaders and figures throughout Europe and America.

[231] I would like to note that what is about to be discussed was not commonplace in my experiences with NSE actors. Usually, issues around race, diversity, and increased engagement were given some consideration, at worst usually ending with an interviewee admitting they'd never given the topic much thought.

to ‘sacrifice’ their culture to accommodate others[232]. Whilst not overt, the connotations of social Darwinism were evident. Given the interview, this could have remained an assumption. However, as the interview concluded and the recording device was switched off, the interviewee turned to me as they were leaving and simply stated ‘You know, we let the Neanderthals die out’. This statement clearly drew upon social Darwinism and racialising tropes that regard non-white peoples as ‘less evolved’ and a threat to continued white dominance of all aspects of society (McLeod, 2010).

7.3 Spirituality and the Cosmos

As noted above, the EuroAmerican framework mobilises a historical narrative from one side of the colonial histories[233] and practices (Wilkes and Hird, 2019). However, despite the construction of such discourses and attempts towards socio-cultural disimagination *vis-à-vis* Outer Space, these are challenged and disrupted through various Ethnofuturisms that draw upon different histories and onto-epistemologies than those of a EuroAmerican bent. Through drawing upon histories that are counterposed to the normative ‘Grand Narrative’ of EuroAmerican frontierism, the Judeo-Christian ideology implicitly bound up within this is critiqued and contested also. Consequently, Ethnofuturisms drawing upon histories from ‘the wrong side of the strange-looking ship that appears out of nowhere’ (Hopkinson, 2011; p.7) do not simply introduce futurisms rooted in different historical narratives, but frequently hold to ontologies other than that of the Judeo-Christian ideology. Through engaging with other ontologies, Ethnofuturist work often proposes different ethics, can challenge typical

[232] The interview was becoming increasingly awkward at this stage, including the interviewee’s body language. Given these cues and uncertainty of how this interview would progress, I decided to move the conversation on. However, with the interviewee’s comments until this point, the connection to social Darwinism is not too far away.

[233] I deliberately use the plural here as colonialism operated is diverse ways, rendering the singular inappropriate (Alam et al., 2004).

delineations of 'Outer' Space, and can highlight the interconnectedness of extraterrestrial operations and terrestrial concerns. I now consider each of these in turn.

7.3.1 Different Ontologies, Another Ethics

Engaging with Ethnofuturist works not only disrupts the hegemony of the EuroAmerican-centric discourses of Outer Space and the inclusionary/exclusionary logics this perpetuates – unwittingly or otherwise – but also draws into question the ethics that stem from the ontology stemming from the Judeo-Christian ideology (Wilkes and Hird, 2019). Whilst normative ideas of extraplanetary ethics can be critiqued through engaging with the idea of 'terracentrism'[234] (Cockell and Horneck, 2004: Collis and Graham, 2013: Spennermann, 2004), Ethnofuturisms draw upon different ontological frameworks to the EuroAmerican imaginary and often propose different ethical frameworks as a result.

Adopting a different ontological framework can instigate a different engagement with temporality[235] and deep time. This engagement with deep time was brought up in conversation with Ethnofuturist authors, some using it as a means of questioning *a priori* assumptions around human-nature relations. Instead of simply regarding asteroids and other planets as merely 'dead rocks' (as some NSE actors characterised them), asteroids were sometimes referenced as unique actors in and of themselves, requiring a (re)consideration of *how* and by what means they can and should be engaged. As Sarah discussed:

> "[Engaging with asteroids differently requires] an awareness that those things existed before we got there and, so, do we really have a right to do these, to

[234] Discussed in Chapter 5.
[235] Temporality is given greater consideration in section 7.4.

harvest . . . It's one thing to observe . . . and it's another thing to harvest, another thing to take."

Through an 'awareness' of an asteroids 'personal'[236] history, this interviewee suggests that an alternative mode of engaging in asteroid mining is required, proffering a different way of 'thinking with' asteroids than the NSE actors' framing of asteroids as 'dead rocks' that are 'devoid of life' (see previous chapter for discussion). Furthermore, through questioning the 'right' to go ahead with this extractivism, the interviewee also troubled normative assumptions surrounding the EuroAmerican-centric discourse of how Outer Space and objects therein are to be engaged with, emphasising the distinctions between observing, harvesting, and taking[237]. Indeed, Sarah proceeded to discuss how approaches to 'harvesting' involve different ways of engaging the non-human by means of ceremony[238] and 'asking' the non-human for the required resources: "There's a ceremony, you ask the tree – this is what we need, we appreciate your willingness. And, of course, there's stories about treaties between humans and non-humans as to those things." This process not only proposes a different means of engaging with the non-human but, through this different process of interacting with the non-human, also challenges normative assumptions of ownership and the privatisation of Outer Space[239]: "So, it's not even so much about, um, you know, we're going to preserve the . . . space objects. It's more like "You know that belongs to someone else, right?"

[236] For want of a better word.
[237] We may think back to the previous discussion in section 7.2.2 where modes of engaging Outer Space other than colonisation and extraction were briefly discussed.
[238] The author was discussing their experience with the Coast Salish peoples.
[239] Discussed in Chapter 6.

This ‘someone else’ does not refer to a person or people but to a spirituality or the object itself, this ontological framework troubling the boundaries between the human and non-human. Indeed, the downgrading of the non-human ‘other’ was brought into relation with broader issues of racism and Outer Space projects. After discussing different stories of how ‘treaties’ between humans and non-humans have been broken in the past, Sarah went on to note that:

> “Those are cautionary tales about treating the environment as an object. So, colonisation, slavery, all of these different ways of oppression happen because, all of a sudden, a sentient thing became and object, right. And indigenous thought treats everything as sentient. Just because you don’t know the language doesn’t mean they’re not smart.”

This idea of not treating asteroids as objects lies once more in contradistinction to the NSE actors’ conceptions of asteroids, disrupting political-economic assumptions of the ‘divide’ between human and object, similar to terrestrial discussions of glaciers and rocks (see Cruickshank, 2005 and Povinelli, 1995 for respective discussions). This author went on to discuss how this different conception of human-non-human relations could be adopted and applied to the asteroid mining sector to inform a different ethics to those that are currently applied *de facto* due to the dominance of the EuroAmerican imaginary. As they went on to say:

> "It's about building an awareness, to me, of that sense [that non-humans are sentient]. Instead of treating these spaces as objects, that just 'they're floating out there, so of course we should use them, develop the technology'. I think it would be really interesting to develop policies and, basically protocols, that recognise [this] . . . and, quite honestly, as I think about it, the West has no method for this, they have no method of addressing an asteroid and saying 'Okay, we need this fuel and we're only going to take this much, is that okay?' and enforcing that."

Through considering this point, the interviewee speaks towards an issue at the core of an ethics predicated upon an ethnocentric discourse through their noting that the 'West has . . . no method of *addressing* an asteroid'. We can read the idea of 'addressing' asteroids in two ways: either as an embodied, physical interaction or as a way of speaking of/towards asteroids. The former of these has been discussed above through the notion of 'ceremony'. The latter is discussed in McDonnell's *Lingua Franca*. Whilst there have been discussions on whether a single international language is required for Outer Space (see Howell, 2018), McDonnell's work provides an inroad for a critical take on this, reminding us that language can inform and (re)create relations to/with objects. In the story, the 'Earthers' are 'mouth speakers', using sound to communicate, whilst the planetary indigenous people are 'signers'; their language does not rely on words. Whilst a critical take on the processes of colonialism and the enforcement of a *lingua franca*, the story's protagonist reminds us that shifting 'language' – or completely removing a language – necessarily shifts worldviews and relations as 'they change everyone else's way of seeing' (2011; p.214). Indeed, the issue(s) of language and its relation to understanding/relating to particular spaces and the cultural heritage that

comes with this are in the Welsh zeitgeist, there being a series of debates on the continued renaming of Welsh place names and the cultural erasure that this brings (see Owen, 2018). Taking these two modes of 'addressing' seriously calls into question how asteroids and the broader Outer Space environ is related to and (mis)understood.

Consequently, engaging with Ethnofuturist imaginaries and the different ontological frameworks adopted and applied therein disrupt the normative, ethnocentric ethics currently adopted and applied. These 'other' ethics bear implications for the human-non-human relations bound up in all aspects of the asteroid mining process and the modes with and through which asteroids and other non-humans are engaged with. Indeed, these different ontological groundings also propose different conceptions of the delineation between 'Outer' Space and (inter)planetary boundedness through which these different ethics operate and confound the EuroAmerican discourse further. It is these areas that I now concern myself with.

7.3.2 No 'Outer' Space

There has been much debate over the decades in defining where, precisely, the boundary between airspace and Outer Space lies and how this may be defined (Lal and Nightingale, 2014). However, the very term 'Outer' Space is predicated upon an arbitrary delineation that is dependant – in part – upon the ontological framework adopted and applied (Posey, 2002). Indeed, this has been noted by Young (1987) in their discussion of Native American views on the space programme. They note that:

> "Native American attitudes towards "outer space" often conflict with the attitudes of the proponents of the U.S. space programme. Rather than applying the metaphor of the "new frontier" or even the term "outer" to this aspect of the cosmos, many Native Americans regard it as encompassed in "Father Sky", part of their network of symbolic associations that integrates all elements of the cosmos." – (p.270)

This dissolution of a distinct 'Outer' Space arose – both implicitly and explicitly – during the course of some Ethnofuturist interviews and in some of the Ethnofuturist SF analysed during this research. This was perhaps most eloquently noted by Sarah when they told me that "there are stories of who She [the Moon] is . . . and nothing is monolithic. Everything is part of a system . . . so Space is a gift: everything is a gift and given in generosity, so we need humility". Whilst interviewing NSE actors and analysing materials associated to the sector, Outer Space was discussed in and of itself without reference to Earth or terrestrial practices[240]. However, whilst interviewing Ethnofuturist authors the topic of asteroid mining frequently expanded to discussions of the Moon, planets, and Earth, linking these places together and blurring the *a priori* divide between the terrestrial and 'Outer' Space.

Whilst work has been undertaken to explore the (post)colonial implications of space programmes (such as Redfield, 2000), these works frequently perpetuate the distinction between the terrestrial and 'Outer' Space. Through focusing solely upon one area or the other, the binary logic of terrestrial and 'Outer' Space is reinforced and, implicitly, so too is

[240] The only times Earth and terrestrial practices arose were regarding policy and to emphasise the complete 'otherness' of Outer Space.

the EuroAmerican-centric ontological framework upon which these spatial conceptualisations are predicated. Engaging with Ethnofuturisms that draw upon alternative ontologies disrupts this *de facto* divide between the terrestrial and extraterrestrial – such as Young's discussion of the concept of "Farther Sky". Consequently, through engaging with an ontological framework that is not grounded in the Judeo-Christian ideology, the EuroAmerican-centric discourse of 'Outer' Space and the arbitrary delineation this creates is confounded. Instead, through engaging with spiritualities and 'other' ontological frameworks, the interconnectedness of 'Outer' Space, terrestrial concerns and the interplays between these are brought to the fore

As noted above, Ethnofuturist works and interviewees often broke down the typical division between the terrestrial and extraterrestrial. Discussions that began with asteroid mining frequently drew upon concerns relating to the Moon, planets, and the terrestrial implications of Outer Space programmes. Rather than merely drawing parallels between these areas, interviewees brought these areas into dialogue with one another, expressing how these celestial bodies, asteroid mining, and the terrestrial are not distinct but constitute parts of an interconnected, systemic 'whole'. Indeed, Young (1987) has detailed how Native American ontologies do not construe 'Outer' Space as separate to Earth, the cosmos instead being an aspect of "Father Sky".

This interconnectedness is detailed in the African-American author Andrea Hairston's *Griots of the Galaxy*[241] , in which the 'body historian' we follow throughout the story returns to their people. They are 'snagged . . . in a magnetic field' that 'lined up [their] electrons' in preparation for them to join their cosmic 'whole'. Their energy becomes aligned with a 'jungle

[241] A part of the *So Long Been Dreaming* collection.

of galactic griots, roots intertwining underground, branches interwoven above, and their fields all lined up' ready to draw them home into the 'bosom of family, connected to deep time'. This can be read as allegorical of the interconnectedness of human-nature relations, 'body historians' taking on the bodies of both humans and non-humans. However, these various permutations of their bodies – or 'energy' if we engage with the metaphor of lining up their electrons – are not simply connected through their immediate (meta)physical being but through deep time and the cosmos[242]. Reading *Griots of the Galaxy* as such collapses typical notions of spatio-temporal boundedness, drawing us instead into considerations of different ontological renderings of spatio-temporalities than that espoused through a EuroAmerican-centric discourse (Croal and Darou, 2002: Posey, 2002: Young, 1987).

Just as *Griots of the Galaxy* plays with – and disrupts – notions of 'Outer' Space, the interconnectedness of the terrestrial and extraterrestrial was expanded further during interviews with Ethnofuturist authors. Rather than discussing asteroid mining exclusively, the processes involved were frequently linked to ethical concerns pertaining to the Moon and terrestrial projects. As one of the Ethnofuturist authors discussed, the concerns about asteroid mining they had heard in their community had:

> "been more about concerns getting to the moon, you know, should we even be on the moon? Because there's stories about who She is, right, and then the technologies that are needed to be harvested here in order to go to the moon . . ."

[242] A broader discussion on temporality is had in the following section so is deliberately skimmed over here.

Whilst concerns surrounding the Moon may at first appear tangential, it is actually pertinent to many proposed extraterrestrial projects, including asteroid mining. Through (re)conceiving 'Outer' Space as a complex interconnected system, the actions within and upon one area bear implications throughout the system. Indeed, the interviewee's comments also trouble the normative assumptions surrounding human-nature relations by highlighting that there are 'stories about who *She* [the Moon] is'. Through discussing the Moon in such away and by engaging with indigenous ontologies, not only are the arbitrary boundaries of asteroid/Moon/Earth/Planet disrupted but so too are the boundaries between the human and non-human, 'personhood' being ascribed to what a EuroAmerican ontological framework often construes as a 'dead rock'[243] (Croal and Darou, 2002: Posey, 2002).

Relating asteroid mining to more systemic concerns did not stop with considerations of the Moon and 'Her' rights. The processes involved in asteroid mining were brought into conversation with terrestrial programmes and processes. As previously noted, some asteroid mining companies have been creating various simulants that replicate the regolith of asteroids, Mars, and the Moon[244]. Whilst the development of these simulants are designed to achieve goals 'out there' in Space, the materials for these simulants are necessarily sourced on Earth and pose a series of issues in and of themselves. Indeed, Sarah noted the issues asteroid mining poses for indigenous groups in a terrestrial context. When asked to elaborate, the interviewee responded:

[243] To use the language of some NSE interviewees.
[244] DSI (2017), 'Asteroid Simulants: Now Commercially Available'. This webpage is no longer accessible.

> "So one [issue] being the creation of Mars simulant from Hawaiian lava and how . . . native Hawaiians are not very happy about that because that's Pèlè's stuff and you don't piss off a volcano Goddess – it's a bad idea!"

This quote neatly surmises a core issue surrounding asteroid mining: it is not simply an abstract endeavour that happens far off in 'Outer' Space but bears implications on a multitude of scales and sites[245]. Though indigenous ontologies disrupt and challenge normative delineations between the terrestrial and 'Outer' Space, it is through drawing attention upon the terrestrial dimensions of these projects where conflicts between the EuroAmerican and indigenous ontologies are at their starkest and most salient. As noted above, there is an ongoing conflict surrounding the mining of sacred Hawaiian rock and the development of asteroid simulants, regarded as a key aspect in the pursuit of developing asteroid mining technologies. Indeed, conflicts surrounding 'Outer' Space projects and sacred lands are not uncommon, mass protests currently occurring due to the construction of the *Thirty Meter Telescope* (TMT) on the sacred mountain Mauna Kea (BBC News, 2019: van Dyke, 2019). Recognising this, Ethnofuturists have and are challenging the normative assumptions surrounding 'Outer' Space, drawing attention to the interconnectedness embedded within the asteroid mining project.

Through engaging with Ethnofuturists, the ontological framework that (re)creates a division between 'Outer' Space and airspace was not the only boundary disrupted. Concerns pertaining to asteroid mining were taken beyond asteroids themselves, being drawn into an

[245] Here we may think of Arboleda's *Planetary Mine* but extend its premise further to consider the *interplanetary* mine.

interconnected and systemic view that frequently broke down boundaries between asteroid/Moon/Planet/Earth. Furthermore, discussing asteroids in this way did not only disrupt the *de facto* logics applied through the dominant EuroAmerican framework used to discuss 'Outer' Space, they also drew attention to the multi-sited and multi-scalar processes and issues involved in the asteroid mining project. Rather than something that simply happens 'out there' in Outer Space, the endeavour involves activities on natural satellites, the immediate space around Earth, and terrestrial projects.

7.4 Competing Temporalities

Just as different histories and ontologies arise through engaging with Ethnofuturisms, multiple temporalities and subsequent relations and temporal orderings arise also. Although the preceding chapter engaged with temporality through its discussion of slow violence, temporality frequently appeared in different ways. Throughout the data collected during this research, temporality arose as a theme within all the data sets – both implicitly and explicitly. Indeed, the very concept of Ethnofuturism – EuroAmerican or otherwise – is fundamentally tied to temporality. It involves the blurring of temporalities through the weaving of *past* (Ethno-) and *future* (-futurism) into a multitude of narratives in the *present*, each Ethnofuturism drawing upon its own series of (inter)cultural specificities and inflections (Hennoste, 2012: Kolcheva, 2015)[246]. The temporalities engaged with when discussing Outer Space can operate as intangible vehicles wherein (de)colonial assumptions and world orderings may be ideologically transported and imposed upon Outer Space and the asteroids therein. Rather than being neutral points of reference, temporal orderings have particular assumptions imbued within them and can operate as a projection or extension of the onto-

[246] Refer to Chapter 3 for a more detailed discussion of Ethnofuturism.

epistemologies ascribed to by any given individual or group (Sojoyner, 2017: Urry, 2016: Vergés, 2017). Depending upon which temporality becomes the dominant framework, certain groups can come to be disenfranchised and excluded from decision-making processes (Sojoyner, 2017: Vergés, 2017), despite the oft-invoked, totalising 'humanity' when discussing Outer Space.

Temporality is a multifaceted and variegated concept, there being numerous competing and conflicting temporalities, including (but not limited to): emergency, institutional, and democratic times (Hassan, 2009); regulatory time (Stengers, 1997: 2000); foresight (van Lente, 2012); and anticipatory time (Szerzynski, unpublished). Indeed, time informs our understanding and conceptions of space in numerous ways, influencing how spaces and places come to be understood and interacted with (Taylor, 2009). However, to consider Outer Space in relation to all of these temporalities would be a vast undertaking and would far exceed the confines of this thesis. Thus, for sake of clarity and brevity, I will focus on two broader temporalities that emerged from the data due to the different 'rhythms' these imply and the resultant impact these 'rhythms' pose for conceptions of asteroid mining. The first of these broad categories is the 'Neoliberal Temporality', referred to as such due to its articulation in support of markets, privatisation, and profit margins. The second category is what I call 'Temporalities of Alterity', ways of framing time and the (inter)actions therein that are counter to a 'Neoliberal Temporality' and advocates for different ways of engaging with asteroid mining as a result. I now discuss each of these in turn.

7.4.1 Neoliberal Temporality

Of the two broad temporalities outlined above, I turn first to consider the 'Neoliberal Temporality'. Broadly speaking, this conceptualisation regards time as something to be

overcome and operated against (Hassan, 2009) in order to maximise the primary goal of private ventures: fiscal profitability (Bridge, 2004: 2014: Wood, 2017). However, whilst I argue that a neoliberal temporality can be seen to operate through the prevailing onto-epistemological framework adopted *vis-à-vis* Outer Space, this may seem a contradiction in terms as far as the temporal horizons involved in Outer Space ventures and a neoliberal temporal ordering are concerned. Indeed, this apparent oxymoronic positioning has been most notably outlined by Valentine (2012). Valentine has noted that there is a temptation to simply regard the NSE sector as nothing more than 'the next step in neoliberal capitalism's search for new profits and markets' (ibid; p.1045). Yet, conceiving of the NSE in this way is incommensurate with finance capitalism's short-term investment strategies, thereby rendering it 'hostile to both the cosmological vision and entrepreneurial practice of NewSpacers' (ibid. p.1045). Instead, Valentine notes that NewSpacers seek to establish space settlements that they regard as essential to long-term human survival and evolution[247].

Whilst this may at first appear to be the case, the vision of NSE actors and a neoliberal temporality are not entirely incompatible. Rather than advocating for a series of projects and visions that are hostile to a neoliberal framework, NSE actors actually mobilise the futures they conceive (including those of human survival noted by Valentine) to not only (re)shape popular imaginaries of the future but also to meet their goals within the neoliberal market. Rather than working towards a future that is beyond the scope of the ever-closer neoliberal time horizon, the reverse is true. NSE actors draw their conceptions of the future into the present, bringing these futures to bear upon the present in multiple ways. Similarly, their profits do not reside in some far-off future. Rather, these futures are articulated and

[247] We may regard these arguments as invoking a *Species Temporality*, couched as it is in notions of long-term human survival.

mobilised to justify and expediate commercial endeavours in the here and now[248]. These range from selling data retrieved from asteroids through satellite programmes launched by asteroid mining firms[249] and saleable 'spin-off' technologies[250] to producing asteroid regolith simulants and selling these to other labs[251]. This is expressly noted by AMC on their website, where they state:

> "We are currently developing a satellite to prospect the near-Earth asteroids (NEAs) for mining candidates. AMC will commercialise this data set in order to fund further development of the Asteroid Mining industry, using the revenues from the Space Resource Database to refocus our R&D on the extraction, processing and utilisation of the available extra-terrestrial materials."[252]

This observation became clear during fieldwork at the NSE conferences attended as part of this research. During the *ESPI* conference in Vienna a handful of presenters gave business-focused talks, all of which alluded to – or directly addressed – issues of time horizons *vis-à-vis* operational capacity. The *SFF* conference was business-focused and repeatedly

[248] Indeed, we may think here about how markets currently trade in Financial Futures and how the market is itself based upon speculation – a protracted means of attempting to predict the future for financial gain.
[249] According to data retrieved from participant observation at the Space Frontier Foundation (2018) and various asteroid mining company websites that discuss 'prospecting' missions such as Asteroid Mining Corporation (2020) and DSI's Prospector-1 mission (Information retrieved from analysed website material (DSI (2017), 'Prospector-1: Searching for valuable resources on a near-Earth asteroid'. This webpage is no longer accessible).
[250] Information retrieved through participant observation and from analysed website material (DSI (2017), 'Prospector-x: An International Mission to Test Technologies for Asteroid Mining'. This webpage is no longer accessible).
[251] For example, DSI produced four types of asteroid regolith simulants in partnership with UCF through a NASA grant, and expanded their simulant portfolio to include Lunar and Martian regoliths also (DSI (2017), 'Asteroid Simulants: Now Commercially Available'. This webpage is no longer accessible).
[252] Information retrieved from AMC (2020), 'The Asteroid Mining Corporation', https://asteroidminingcorporation.co.uk/ [accessed June 2020].

discussed the need to 'lean on the government'[253] for policy reform to both 'open' Outer Space and overcome what many regarded as cumbersome and time-consuming restraints[254]. As one conference attendee noted: "Things move much faster in the private sector. When the government's involved, things become much slower. Everything has to be signed off all the way to the president"[255]. This attendee's remark neatly encapsulates the broader attitude within the NSE and their perception of governmental oversight and processes. The temporal rhythms of government Departments and Agencies are regarded as burdensome to the NSE project and its pursuit of capital. However, if we regard these government bodies as democratic institutions, the temporal mismatch becomes clear due to these institutions operating through 'democratic time'[256].

In answer to these cumbersome processes and regulations, there has been a concerted effort on the part of NSE actors to lobby governments and shape Outer Space policy into something more conducive to private interests. A speaker at the *ESPI* conference and several at the *SFF* conference[257] all made mention of how their companies had been involved in lobbying the US government into passing the US SPACE Act 2015 – a policy that has begun opening Outer Space for asteroid mining and other private extraterrestrial endeavours. Indeed, these lobbying efforts were brought together with temporality. Akin to the attendee's above comment, an SFF speaker remarked upon the 'issue' with 'democratic time' (Hassan, 2009) and the need to lobby government: "Business turnover operates at months. The

[253] Quote from an SFF talk taken during Participant Observation.
[254] The arguments for relaxing policy were hardly surprising as SFF is a libertarian NSE advocacy group.
[255] Participant observation note from SFF conference.
[256] A term used by Hassan (2009) when discussing institutions of liberal democracy that adhere to 'principals of universal suffrage, parliamentary representation, and a system of checks and balances that (more or less) [keep] the judiciary, the executive and the legislature separate and distinct' (p.1).
[257] I have avoided using the names of speakers here to assure their anonymity (notes made during participant observation).

Government budget takes years at a time, so there's a need to lean on the Government"[258]. The observation here makes explicit the mismatching of temporalities implemented by public and private entities, emphasising the vast differences in temporal rhythms engaged with and enacted by NSE actors and government bodies.

Furthermore, the claim that there is 'a need to *lean* on the Government' provides further emphasis on the conflict that exists between the temporal engagements of the democratic and neoliberal logics of temporality. The encouragement to 'lean' on the democratic structures has clear implications of applying pressure or, to couch it in neoliberal terminology, 'market forces', a phrasing that itself contains connotations of coercion (Wood, 2017). Through utilising this terminology and constructing a series of futures that are 'threatened' by a slower (i.e. democratic) temporality, actors within the NSE often argued against democratic institutions and policies. As with the process of socio-cultural disimagination outlined above, this contestation of democratic institutions and temporalities is another process of disimagination. This is down to the temporal mismatch that results in the private (i.e. neoliberal) sector feeling the need to 'lean' on government. Specifically, disimagination is a process whereby 'stories, images, institutions, discourses, and other modes of representation' are used to foreclose any means through which to reimagine the future and challenges democratic institutions (Giroux, 2014; pp.26-7). Furthermore, this framing of time – the private sector operating at 'months' and the government at 'years' – illustrates further how the private sector regards time as a barrier to accruing capital rather than something to be worked with or through (Bridge, 2004: 2014: Wood, 2017).

[258] Quote taken from participant observations notes of the *SFF* conference.

These two modes of engaging a 'Neoliberal Temporality' – through drawing futures into the present to further financial gain and 'leaning' on democratic institutions to operate quicker – are both spurred on through NSE actors' foreclosing of time. In these moments, the NSE 'future'[259] was portrayed as being something fragile that needed to be acted upon with haste. As one SFF presenter said to the conference audience: "This is a crucial point in history – perhaps the most important in the past 300-400 years"[260]. This statement clearly indicates the supposed fragility of the NSE future, creating a sense of urgency through foreclosing the future whilst simultaneously placing the emphasis on the present. Furthermore, this statement also invokes a history by declaring the present moment to be the most important point in the past 300-400 years. This, coupled with the context of being in the *Space Frontier Foundation* conference, is a clear invocation of the Western frontier history and its associated narratives[261]. Of course, discussions of frontierism within these settings used specific versions of white settler colonialism that ensued in the 'New World', omitting issues and processes such as enclosure, working land to produce 'value', and the displacing of indigenous/non-Western systems and frameworks (Bhabha and Comaroff, 2002: Hesse, 2002: Loomba et al., 2005: Parry, 2002: Wilkes and Hird, 2019: Wood,2017: Young, 2001).

This foreclosing of the future and perpetuation of its seeming fragility was stated again by another NSE speaker: "We'll either look back and say we made it or look back and think we blew it"[262]. Once more, the phrasing here is used to create a sense of foreclosure, contracting the temporal dimensions and spurring a sense of urgency within the NSE sector

[259] Always referred to in the singular during conferences and interviews, giving the semblance of on organised project despite its never being fully knowable.
[260] Quote from participant observation of the *SFF* conference.
[261] The colonisation and settling of the 'New World' was used in other talks also. Perhaps most notably, this narrative – and associated imagery – was used by the CEO of DSI at the time. They used this imagery and the settler-colonial narrative to support the ideas behind asteroid mining and ISRU.
[262] Quote taken from participant observation notes.

and around its cause(s). These statements also clearly construct time as something to be worked against or as something that is working against the NSE sector and its goals. Through conveying time in such a way, the actions of NSE actors are influenced and informed. A foreclosing of time and the risks posed to the NSE future provide the impetus to 'lean' on governments and democratic institutions in an attempt to ensue fiscal profits are maintained so NSE actors do not 'look back and think [they] blew it'.

However, although those at the NSE conferences frequently framed and discussed time in terms that lead to ideas of foreclosure and subsequent urgency, it is worth noting that not all NSE actors doggedly adhere to this position. One of my interviewees agreed that there is a need to hurry up and seize the opportunities, they also noted the need to plan thoroughly prior to undertaking any largescale plans: "I think we need to be in a hurry to do it [asteroid mining], but not in so much of a hurry that we don't figure these things out before we get too far ahead of ourselves". This remark, made by an interviewee that attended the *SFF* conference, serves as a pithy reminder. The NSE sector frequently frames Outer Space projects through a 'Neoliberal Temporality' that seeks to foreclose time and overcome what are often seen as inconvenient delays posed by 'democratic time' (Hassan, 2009). However, there is recognition by some actors that whilst there is a need to 'hurry' – to beat the foreclosing of this future – there is also an awareness by some of the need to mitigate risks.

Consequently, whilst the visions of NSE actors at first appear to contradict the temporal framework of neoliberal capitalism (Valentine, 2012), they actually mobilise futures, marketing – and profiting – from these future visions. This is achieved through a combination of a discourse that positions the desired future as fragile and – relatedly – creating a sense of urgency, a 'do-or-die' narrative. Despite this being prevalent throughout the sector, there are

some actors who concede that the urge to hurry needs to be tempered to mitigate risks and 'externalities' (Bridge, 2013). Therefore, if we seek a thorough engagement with futures that are constructed outside of the 'Neoliberal Temporality', we must look beyond the visions and imagined socio-material relations of the NSE. Such futures and different temporalities can be found in Ethnofuturist works, which I will now discuss.

7.4.2 Temporalities of Alterity

The second broad temporal rhythm that emerged from the data was what I call 'Temporalities of Alterity'. These are ways of framing time and the (inter)actions therein that operate counter to the 'Neoliberal Temporality'. Given how engagements with time inform relations to space and place, and the (inter)actions that occur therein (Hassan, 2009: Oppermann et al., 2020: Taylor, 2009: Urry, 2014: Walker, 2021: Walker et al., 2020), 'Temporalities of Alterity' propose different socio-material relations through conceiving of time through different onto-epistemological frameworks than those adopted by the NSE and actors therein. I use the term 'alterity' here not simply to indicate that this grouping of time is different to those discussed above, but also as a means to refer to that which is construed as 'Other'. Other in the sense of existing outside, or counter to, those temporal logics described above, and Other in the sense of colonial constructions of Other-ness, as that or those that are discounted from having a say equal to the ethnic majority and, consequently, have to contest and attempt to (re)negotiate that which has been laid down by the EuroAmerican onto-epistemological framing. These temporalities of alterity refer to those constructions of time that operate through post-/decolonial logics and must necessarily be referred to in the plural, rather than the singular. This plurality serves both as an acknowledgement of the multiple decolonial framings of, and relations to, time and this framing operates as a

challenge to the construal of time in the singular, such as that conceived of in popular (read *Western*) understandings of time. These temporalities of alterity draw upon onto-epistemologies that challenge *a priori* assumptions within Western orderings of time. These counter-constructions result from their point(s) of reference originating from radically 'other' origins that inform the *Ethno*- of Ethnofuturism (Hennoste, 2012: Kolcheva, 2015).

Temporalities of alterity were drawn upon in interviews conducted with Ethnofuturist authors and appeared in the Ethnofuturist SF engaged with in numerous ways. Many instances explicitly refuted the 'Neoliberal Temporality' and often critiqued democratic temporality also, referencing how these temporalities articulate Western constructions of time. Indeed, these discussions challenged the temporal orderings through critiquing and problematising the points of historical reference, at times operating to 'blur' temporal orderings to question linear constructions of time, and argued for engaging with slower temporal rhythms in order to relate to, and learn with, an asteroid's body. These points all problematise the *a priori* assumptions adhered to by the EuroAmerican ordering discussed above.

The first of these points – that of problematising the points of historical reference drawn upon – is particularly pertinent given one of the conference quotes used above, specifically the one used to create the sense of immanence through constructing contemporary developments of asteroid mining as being "perhaps the most important [point] in the past 300-400 years". The time period here is likely an intentional reference to the 'discovery' of the 'New World' and the subsequent colonial expansion into the 'Western Frontier'. The importance ascribed to this historical point is likely a reference to the discovery

of the 'New World' and the prosperity and 'progress' it heralded for colonising nations[263]. However, as this suggests, this period only seems 'important' in a positive sense of the word if the histories of the EuroAmerican ordering of time is applied. A very different reading occurs if one considers the reading(s) produced through engaging 'Temporalities of Alterity' (we may think back to Hopkinson's point of being on the wrong side of ships that appear out of nowhere here). Reading through this alterity produces a vastly different reading of the history and importance the conference attendee noted above. It requires that we think with and through these historical engagements in ways that are drastically opposed to the norm frequently ascribed to, unsettling grand historical narratives and questioning how projects operating in 'frontiers' can/should be related to and engaged with[264]. As Hopkinson notes, for many of the world's population this narrative does not capture the experience(s) produced by this event and, consequently, forces us to ask fundamental questions of the assumptions made and perpetuated by the EuroAmerican-centric 'Neoliberal Temporality' discussed above. Interrogating such assumptions inevitably leads to debates around which humanity is spoken of/for in such totalising concepts and, ultimately, who owns the cosmos and has a say in how it is engaged with and related to.

A further point made through discussions on temporalities of alterity is that of the slower temporal rhythms that can or should be engaged with when encountering asteroids. As Sarah said when discussing different temporal engagements:

[263] I deliberately use colonial terminology here to emphasise the point – 'prosperity' and 'progress' are deeply contested terms and the socio-economic calculus used to review the 'success' of these endeavours is not absolute and is itself subjective.

[264] We may think here of a large body of work within postcolonial studies. Select references include Bhabha and Comaroff, 2002: Fanon, 2001: Hesse, 2002: Loomba et al., 2005: McLeod, 2010: Parry, 2002: Young, 2001.

> ". . . what I love about that idea of you don't claim a piece of land until you've lived there five generations, it's because you can see it. It takes that long, that much observation, to say 'oh, okay, when the conditions are this way because of the weather, then we can use this part, but otherwise in these conditions it's swamp'. You have to wait a certain amount of time before you can go in and then when it hits a particular, you know. . . it takes a long time to make these observations and, um, that also is not built into Western culture, this idea of waiting, to understand a system."

Contrary to the temporal engagements advocated for under the neoliberal ordering(s) of time discussed above, this temporality of alterity posits that such engagements should actually slow in order to learn with the asteroid over a longer period than that demanded through constructing time as a barrier to be overcome. The interviewee suggests a relational engagement with asteroids, a multi-generational engagement with an area such as an asteroid invoking the idea of becoming with, rather than overcoming. Such a relational construction and the slower temporal rhythm utilised, it is argued, leads to a greater understanding of the system being engaged with. As the interviewee notes, this is not "built into Western culture", thereby suggesting that the EuroAmerican constructions of time are likely insufficient to understand, and work/become with, asteroids[265]. Indeed, this tension is also explored in Kim Stanley Robinson's *Mars* Trilogy where Arkady Bogdanov – a space navigator and one of Mars' first hundred colonisers – actively addresses the issues of

[265] Indeed, we may think back to the section on Spirituality and the Cosmos here -

dominating a planet(oid) rather than becoming 'with' and questioning the onto-epistemological frameworks brought to the planet:

> ". . . some of us here can accept transforming the entire physical reality of this planet, without doing a single thing to change ourselves or the way we live . . . And so I say that among the many things we transform on Mars, ourselves and our social reality should be among them" (Robinson, 1993; p.89).

Whilst being present within the text of a white Ethnofuturist, this mode of imagining a slower 'becoming with' and what Robinson writes represents a potential confluence point between these slower temporal rhythms and multiplanetary environmentalism[266]. Construing of temporal engagements with asteroids in such a way disrupts the understanding(s) created and perpetuated by Western constructions of temporality and the modes of engagement these create as a result.

Through considering these temporalities, it is evident that the way(s) in which time is constructed influences the manner(s) in which asteroids are related to, constructed, and engaged with (Hassan, 2009: Taylor, 2009). The temporality engaged bears many implications for the way(s) 'we' conceive of asteroids' socio-materialities. Some temporalities, such as the democratic and neoliberal, contain within them colonial assumptions and positionings (Sojoyner, 2017: Vergés, 2017), serving to (re)create power relations found on Earth. Through these processes, the cosmos is racialised further[267], through perpetuating EuroAmerican

[266] For an in-depth discussion on the Mars Trilogy and multiplanetary environmentalism see Huston (2002).
[267] We may think back here to the subsection on racializing the cosmos.

futurisms and settler-colonial logics bound up within this (Arendt, 1958: Giroux, 2014). However, temporalities of alterity propose another set of temporal engagements that engender very different relations to and with the asteroidal, problematising the *a priori* assumptions at the core of democratic and neoliberal temporalities, oppugning their historical frame(s) of reference, and suggesting slower temporal rhythms that result in creating very different relations to those of the democratic/neoliberal ordering of time.

Indeed, the ability for private actors to operate through faster temporal rhythms was noted by one Betty: "Corporations can drive policy faster and more effectively, and that can be a bad thing, that can be a really bad thing". Whilst the interviewee clearly agrees that the private sector – through its ascribing to a 'Neoliberal Temporality' – is able to 'drive policy faster and more effectively' there is clear scepticism that this faster temporal rhythm is indeed a good thing. It is interesting to note that this is a point of agreement with some in the NSE sector. As discussed in the preceding subsection, there are actors within the NSE sector that – despite working within the neoliberal framework – also agree that the speed with which private projects are being pursued. The NSE interviewee's belief that 'we need to be in a hurry to do it [asteroid mining]' resonates with the above interviewee's belief that 'corporations can drive policy faster and more effectively' and, similarly, both expressed caution whilst noting this. The Ethnofuturist above notes how this can be a 'bad thing' and the NSE consultant noted how issues needed to be 'figure[d] . . . out before we get too far ahead of ourselves'. There is a clear indication here that there are actors within the NSE and Ethnofuturist whose views are not entirely dissimilar and presents a pithy reminder that these groups are not mutually exclusive and do not exist in binary positions to one another[268]. There

[268] This spectrum and social 'messiness' (to borrow a term from Law (2004)) is something to be explored in future research, as the limitations posed by the thesis do not permit extensive elaboration on this.

are those in the NSE sector who believe a slower temporal rhythm is needed in planning and approaches to Outer Space activities, indicating that a greater engagement with 'Temporalities of Alterity' is a promising site of study for future research.

7.5 Towards Another Outer Space

Through engaging with Ethnofuturist works a series of challenges are posed to the seemingly hegemonic discourses of asteroid mining futurity. The disimagination process involved in constructing and maintaining a specific, neoliberal futurity is frustrated through future imaginaries being proffered that draw upon histories 'outside' of the Western colonial history. These Ethnofuturisms explore a variety different ways of engaging with asteroids, of how we could (not) interact with them and their mining, and propose different means by and through which the delineation of 'Outer' Space should be negotiated or refuted. Moreover, these Ethnofuturisms also ask use to consider different temporal engagements with asteroid mining and Outer Space futurity more broadly. They open conversations towards different histories, modes of thought, and ways of being that ask us to be open towards different ways of being other than a Eurocentric, neoliberal mode of existence. As one interviewee eloquently put it:

> "They didn't conquer [the Pacific] – it wasn't about conquering. It was about exploring, it was about seeing what's out there and, so, what if we approached the solar system in the same way? What would that do to our minds?"

Chapter 8: Concluding Remarks

This thesis has sought to explore asteroid mining and (de)colonial futurity through an empirically-grounded study that draws upon a selection of geographical subfields and contributes to the burgeoning Social Studies of Outer Space. It has considered a range of issues, looking to decenter capitalism, Eurocentrism, and terracentrism in a variety of ways. It began with a conceptual framework that drew together multiple strands of geographical and social scientific work: bringing together work on capitalism, extraction, expansionism, disimagination, Ethnofuturism, and conceptual provocations relating to terracentrism. Through combining these conceptual areas, this research has become grounded in (de)colonial theory, social futures, and geosocial thought; asking how asteroids and Outer Space are being (re)imagined by asteroid mining industry actors and Ethnofuturists alike.

Drawing upon the three 'decenterings' and this conceptual framework, the subsequent discussion broadly looked at several areas. Firstly, it discussed how Outer Space is being conceptually and imaginatively 'opened' to permit extractive activities such as asteroid mining: exploring how asteroids – and Outer Space more broadly – are being (re)framed as exploitable objects that bear the potential to permit a host of promissory futures. It then moved on to consider how asteroids are (re)constructed, the NSE and its actors creating narratives around various material groupings found within asteroids, generating and (re)interpreting data to render asteroids provisionally 'knowable'. The materiality of asteroids and the extraplanetary context of Outer Space were used as provocations to explore the implications of terracentric thought when thinking through and within a multiplanetary context.

Secondly, the conversation turned its attention to the processes by and through which the Outer Space and asteroid 'frontier' is being enclosed: enclosed from a common-pool

resource to permit private, capitalist exploitation. It explored how this is being achieved through the developing legal framework that surrounds the nascent industry and the attendant discourses being (re)created to support the commercial exploitation of asteroids: specifically, through a combination of a 'greening' discourse and a discourse of capitalistic opportunity. It then turned to occupy itself with the issues of 'excess' posed by any extractive industry, exploring some of the potential issues that arise through asteroid mining and how these are (not) being addressed. Once more, the issues posed by and through this mining 'excess' were brought into conversation with (extra)planetary forces to consider the implications this matter poses in an extraterrestrial context.

Finally, the conversation turned its focus onto the works of Ethnofuturists. It explored how Outer Space and asteroids are being reimagined through work that draws from experiences that are not Eurocentric and that concern themselves – implicitly or explicitly – with challenging *de facto* conceptions of Outer Space futurity. It began by discussing Ethnofuturist reimaginings, exploring how the seemingly hegemonic Eurocentric imaginary of Outer Space futurity is being frustrated, critiqued, and forged anew. It then moved to consider how Ethnofuturists not only challenge the 'imaginary' but how this has material implications for how asteroids are potentially thought about: discussing how the different temporalities by and through which asteroids become 'known' is disrupted, opposing or subverting the popular narratives espoused by NSE actors. Through this, the discussion then explored some of the ways in which this can open new avenues of thought regarding asteroids and how they are engaged with, suggesting different relational onto-epistemologies can be (re)made around asteroids.

It is hard to concisely conclude a discussion on something as vast and far-reaching as Outer Space: infinite not only in its spatiality but also in its capacity to invoke the imagination and to be reimagined itself. Indeed, the term 'conclusion' implies an ending: something antonymous to the vastness of space and the imaginaries it inspires. Consequently, rather than 'conclude' – to close this conversation – it is perhaps more fitting to consider this research and its attendant discussions as a tentative opening towards further deliberation. Opening towards the ability to critically reimagine the social futures of Outer Space and asteroids; opening relationships with asteroid materiality that is not necessarily contingent upon colonial and capitalist onto-epistemological frameworks of domination and dogged profiteering; and open to the extraterrestrial context within which these operations are set to take place – asking how we may begin to think beyond the planetary whilst we are still in the midst of grappling with planetary geosocial thought on our own dynamic rock.

With this notion of 'opening' in mind, it is fitting to note some of the directions future research within the Social Studies of Outer Space could take to develop this nascent area of study further. There is an abundance of different theories that would produce new readings of Outer Space and its attendant futurities. Whilst the multitude of different theoretical lenses through which to approach the Social Studies of Outer Space are too numerable to list, particular focus on feminist readings of Outer Space futurity would be particularly interesting and timely. As noted at the outset of this work, whilst this research has been grounded in postcolonial and anti-capitalist critique/theory, exploring asteroid mining and the NSE through a feminist lens would be particularly fruitful and would intersect well with the work produced here. Indeed, the principal reason for its exclusion within this work has been due to the constraints imposed by the project's wordcount. Consequently, whilst there are numerous theoretical approaches that would produce interesting analyses of the NSE and

Outer Space futurity, future research approaching this topic from a critical feminist perspective would be most welcome and interesting.

Beyond the multiplicity of (re)readings and analyses that could be produced through engaging with various theoretical approaches, future research within the Social Studies of Outer Space can broadly be thought of through three areas. These are the terrestrial dimensions of the NSE, the Extraterrestrial, and the 'in-between'. Within the terrestrial dimensions, encouraging areas for future research would be around issues of land rights (such as those currently highlighted in Hawaii, Australia, and elsewhere) and how these are being (re)negotiated, labour-capital relations and the privatisation of the Commons, matters of pollution and environmental concern (re)produced through the aerospace sector, the ethical sourcing of materials/the supply chains of Outer Space endeavours, and the underlying ideologies underpinning current legislation and debates related to these. Perhaps the most interesting piece of work for the Social Studies of Outer Space would be to create a space of active dialogue between Outer Space forums and Indigenous peoples – for example, seeing what can be achieved through bringing UNCOPUOS and the UN Permanent Forum for Indigenous Peoples together and seeing how policies and practices can be improved or affected through this process.

The extraterrestrial dimensions for future research include a (re)conceptualisation of ethics in a multiplanetary context (i.e. asking what a Martian ethics, Lunar ethics, and so on would look like), a more thorough consideration of terracentrism and its implications for the Social Studies of Outer Space, what it means to meaningfully engage with the Anthropocene in Outer Space, matter of multiplanetary and subsurface imaginaries, and what these look like when engaging with Indigenous/non-Western ideas pertaining to governance. The 'in-

between' dimension concerns ideas of where Earth ends and Outer Space begins. Whilst this area has been debated in past geopolitical forums, here I do not simply mean where an imaginary line sits separating the two. Rather I take this to mean a transient space that poses its own site of geopolitical contestation, various orbital slots and heights being fought over by various actors. Exploring how these are (de)politisised and the relations constructed around these would pose another fertile area for future research.

These matters are not confined to asteroid mining but concern a whole host of activities that comprise the NSE. Each of these sectors pose promising sites for future research that will enliven the Social Studies of Outer Space for many years to come and appear to being increasingly salient as Outer Space activities intensify.

Bibliography

Abu-Lughod, L. and Lutz, C. A. (1990), 'Introduction: emotion, discourse, and the politics of everyday life'. In: Lutz, C. A. and Abu-Lughod, L. (eds), *Language and the politics of emotion*, Cambridge: Cambridge University Press.

Adilov, N., Alexander, P. J. and Cunningham, B. M. (2018), 'An economic "Kessler Syndrome": A dynamic model of earth orbit debris', *Economics Letters, 166*, pp.79-82.

Agricola, G. (1556) [1950], *De Re Metallica*, translated by Hoover, H. C. and Hoover, L. H, New York: Dover.

Aitken, S. C. (1997), 'Analysis of texts: armchair theory and couch-potato geography'. In: Flowerdew, R. and Martin, D. (eds), *Methods in Human Geography: a guide for students doing research projects*, Harlow Longman.

Aitken, S. C. (2005), 'Textual analysis: reading culture and context'. In: Flowerdew, R. and Martin, D. (eds), *Methods in Human Geography: A guide for students doing a research project*, Harlow: Pearson Prentice Hall.

Alam, M., Lawrence, S. and Nandan, R. (2004), 'Accounting for economic development in the context of post-colonialism: the Fijian experience', *Critical Perspectives on Accounting, 15(1)*, pp.135-157.

Allen, C. (2017), 'On Being A Working Class Academic: A Personal Reflection', *Huffington Post*, https://www.huffingtonpost.co.uk/dr-chris-allen/working-class-pay-gap_b_14423132.html [23.01.2017].

Alvarez, L.W., Alvarez, W., Asaro, F. and Michel, H. V. (1980), '"Extraterrestrial cause for the Cretaceous–Tertiary extinction"', *Science, 208(4448)*, pp.1095–1108.

Alvarez, T. (2020), *The Eighth Continent: An Ethnography of Twenty-First Century Euro-American Plans to Settle the Moon*, Unpublished Thesis, accessible at: https://www.proquest.com/docview/2452109023?pq-origsite=gscholar&fromopenview=true

Ambrose, J. (2020), 'Ecotricity founder to grow diamonds 'made entirely from the sky'', *The Guardian*, https://www.theguardian.com/environment/2020/oct/30/ecotricity-founder-to-grow-diamonds-made-entirely-from-the-sky [30.10.2020].

Anantatmula, V. (2013), 'U.S. Initiative to Place Weapons in Space: The Catalyst for a Space-Based Arms Race with China and Russia', *Astropolitics, 11(3)*, pp.132-155.

Anonymous, (2017), 'How do you finish a PhD when, as a working-class student, you don't feel you belong?', *The Guardian*, https://www.theguardian.com/higher-education-network/2017/aug/11/how-do-you-finish-a-phd-when-you-dont-feel-you-belong-at-university [12.08.2017].

ap Dyfrig, R. (2015), 'Cambrofuturism: Welsh UFOs, alien and futurists', *Medium*, https://medium.com/@nwdls/cambrofuturism-5df99c0999df [22.02.2018].

Arendt, H. (1958), *The Human Condition*, Chicago: Chicago University Press.

Atkinson, P. and Hammersley, M. (1994) 'Ethnography and Participant Observation'. In Edited by: Denzin, N. and Lincoln, Y. (eds), *Handbook of Qualitative Research*, Thousand Oaks: Sage.

Attfield, R. (2011), 'Beyond Anthropocentrism', *Royal Institute of Philosophy Supplement, 69*, pp.29-46.

Attfield, S. (2016), 'Rejecting Respectability: On Being Unapologetically Working Class', *Journal of Working-Class Studies, 1(1)*, pp.45-57.

Bagnall, S. (2017), 'Snowdonia satellite launch pad bid underway', *Daily Post*, https://www.dailypost.co.uk/business/snowdonia-satellite-launch-pad-bid-13443140 [07.08.2017].

Bakare, L. (2014), ' Afrofuturism takes flight: from Sun Ra to Janelle Monáe', *The Guardian*, https://www.theguardian.com/music/2014/jul/24/space-is-the-place-flying-lotus-janelle-monae-afrofuturism [17.06.2015].

Bakker, K. and Bridge, G. (2006), 'Material worlds? Resource geographies and the 'matter of nature'', *Progress in Human Geography, 30(1)*, pp.5-27.

Bardi, U. (2013), *Extracted: How the Quest for Mineral Wealth Is Plundering the Planet,* Vermont: Chelsea Green Publishing.

Barnett, C. (2012), 'Postcolonialism: Space, Textuality and Power'. In: Aitken, S. and Valentine, G. (eds), *Approaches to Human Geography*, London: Sage.

Barry, A. (2010), 'Materialist Politics: Metallurgy'. In: Braun, B. and Whatmore, S. (eds), *Political Matter: Technoscience, Democracy and Public Life*, Minneapolis: University of Minnesota Press.

Baxter, J. and Eyles, J. (1997), 'Evaluating Qualitative Research in Social Geography: Establishing 'Rigour' in Interview Analysis', *Transaction of the Institute of British Geographers, 22(4)*, pp.505-525.

BBC News (2012), 'Plans for asteroid mining emerge', https://www.bbc.co.uk/news/science-environment-17827347 [24.04.2012].

BBC News (2019), 'All pupils should learn Welsh history say opposition AMs', *BBC News*, https://www.bbc.co.uk/news/uk-wales-politics-48690433 [23.03.2020].

Becker, H. S. (1958), 'Problems of Inference and Proof in Participant Observation', *American Sociological Review, 23(6),* pp.652-660.

Berger, R. (2015), 'Now I see it, now I don't: researcher's position and reflexivity in qualitative research', *Qualitative Research, 15(2)*, pp.219-234.

Bhabha, H. K. (2004), 'The "Other" Question'. In: Easthope, A. and McGowan, K. (eds), *A Critical and Cultural Theory Reader*, Maidenhead: Open University Press.

Bhabha, H. K. and Comaroff, J. (2002), 'Speaking of postcoloniality, in the continuous present: a conversation'. In: Goldberg, D. T. and Quayson, A. (eds), *Relocating Postcolonialism*, London: Blackwell Publishers.

Bharmal, Z. (2018), 'The case against Mars colonisation', *The Guardian*, https://www.theguardian.com/science/blog/2018/aug/28/the-case-against-mars-colonisation 30.08.2018].

Billings, L. (2006), 'To the Moon, Mars, and Beyond: Culture, Law, and Ethics in Space-Faring Societies', *Bulletin of Science, Technology & Society, 26(5)*, pp.430-437.

Bilmes, J. (1992), 'Mishearings'. In: Watson, G. and Seiler, R. M. (eds), *Text in Context: Contributions to Ethnomethodology*, London: Sage.

Binns, C. (2019), *Experiences of Academics from a Working-Class Heritage: Ghosts of Childhood Habitus*, Cambridge: Scholars Publishing.

Birtchnell, T. and Urry, J. (2013), '3D, SF and the Future', *Futures, 50,* pp.25-34.

Bland, J. (2015), 'Afrofuturism to everyday futurists: new kinds of artists, power & tech', *The Guardian*, https://www.theguardian.com/technology/political-

science/2015/mar/11/afrofuturism-to-everyday-futurists-new-kinds-of-artists-power-tech [18.01.2016].

Bott, E. (2010), 'Favourites and others: reflexivity and the shaping of subjectivities and data in qualitative research', *Qualitative Research, 10(2)*, pp.159-173.

Bould, M. (2007), 'The Ships Landed Long Ago: Afrofuturism and Black SF', *Science Fiction Studies, 34(2)*, pp.177-186.

Bourdieu, P. (1992), *An invitation to reflexive sociology*, translated by Wacquant, L., Oxford: Polity Press.

Bradshaw, M. and Stafford, E. (2005), 'Qualitative Research Design and Rigour'. In: Hay, I. (ed.), *Qualitative Research Methods in Human Geography*, Oxford: Oxford University Press.

Braudel, F. (1982), *The Wheels of Commerce*, London: William Collins Sons & Co Ltd.

Braun, B. and Whatmore, S. (2010), 'The Stuff of Politics: An Introduction'. In: Braun, B. and Whatmore, S. (eds), *Political Matter: Technoscience, Democracy and Public Life*, Minneapolis: University of Minnesota Press.

Brechin, G. (1999), *Imperial San Francisco: Urban Power, Earthly Ruin*, London: University of California Press.

Brennan, S. (2019), '£1m sweetener to store nuclear waste in Denbighshire fails to woo councillors', *Daily Post*, https://www.dailypost.co.uk/news/north-wales-news/1m-sweetener-store-nuclear-waste-16015159 [22.03.2019].

Bridge, G. (2000), 'The social regulation of resource access and environmental impact: production, nature and contradiction in the US copper industry', *Geoforum, 31*, pp.237-256.

Bridge, G. (2004), 'Mapping the Bonanza: Geographies of Mining Investment in an Era of Neoliberal Reform', *The Professional Geographer, 56(3)*, pp.406-421.

Bridge, G. (2009), 'Material Worlds: Natural Resources, Resource Geography and the Material Economy', *Geography Compass, 3(3)*, pp.1217-1244.

Bridge, G. (2010), 'Geographies of peak oil: The other carbon problem', *Geoforum, 41(4)*, pp.523-530.

Bridge, G. (2013), 'The Hole World: scales and spaces of extraction', *New Geographies, 2*, pp.43-48.

Bridge, G. (2014), 'The Resource Archipelago: spatial aesthetics and resource ecologies'. In: Arns, I. (ed.), *World of Matter*, London: Sternberg Press.

Britain Has Class (2017a), '"You Close Off a Part of Yourself": Anonymous Account of a Working Class Academic', *Britain Has Class*, https://britainhasclass.org/archive/2017/11/8/you-close-off-a-part-of-yourself-anonymous-account-of-a-working-class-academic [02.03.2018].

Britain Has Class (2017b), 'On Pretending', *Britain Has Class*, https://britainhasclass.org/archive/2017/7/15/on-pretending [02.03.2018].

Brooks, S. (2017), *Why Wales Never Was: The Failure of Welsh Nationalism*, Cardiff: University of Wales Press.

Broughton, A. (2013), 'Land Grabbing: A New Colonialism', *Green Social Thought, 61*, pp.25-29.

Brown, N., Rappert, B. and Webster, A. (2000), 'Introducing Contested Futures: From *Looking into* the Future to *Looking at* the Future'. In: Brown, N., Rappert, B. and Webster, A. (eds), *Contested Futures: A sociology of prospective techno-science*, Aldershot: Ashgate.

Buck, S. J. (1999), *The Global Commons: An Introduction*, London: Earthscan Publications Ltd.

Burnett, C. (2017), 'A Danger to Power', https://www.britainhasclass.org/post/a-danger-to-power [24.11.2017].

Busby, E. (2019a), 'Number of state school pupils attending university drops despite efforts to widen access', *The Independent*, https://www.independent.co.uk/news/education/education-news/state-school-students-uk-university-attendance-higher-education-statistics-agency-russell-group-a8768411.html [10.04.2019].

Busby, E. (2019b), 'Poorer students now even more likely to drop out of university than richer peers', *The Independent*, https://www.independent.co.uk/news/education/education-news/university-dropout-rates-students-rich-poor-education-a8812526.html [10.04.2019].

Bush, B. (2006), *Imperialism and Postcolonialism*, London: Pearson Longman.

Byrne, G. (2015), 'Coming to Terms With Being a Working Class Academic', *Sociology Lens*, https://www.sociologylens.net/article-types/opinion/coming-to-terms-with-being-working-a-working-class-academic/14799 [02.03.2018].

Cambrian News (2017), 'Calls to focus on Welsh history', *Cambrian News*, https://www.cambrian-news.co.uk/article.cfm?id=118030&headline=Call%20to%20focus%20on%20Welsh%20history&sectionIs=news&searchyear=2017 [12.12.2017].

Caroti, S. (2011), 'Defining Astrosociology from a Science Fiction Perspective', *Astropolitics, 9(1)*, pp.39-49.

Carr, E. H. (1981), *What is History?*, Hammondsworth: Penguin Books Ltd.

Carr, M. (2010), 'Slouching towards dystopia: the new military futurism', *Race & Class, 53(1)*, pp.13-32.

Carson, C. (2017), 'Academia Needs Working Class Kids', *Britain Has Class*, https://www.britainhasclass.org/post/academia-needs-working-class-kids [24.11.2017].

Carter, J. (2020), 'A Bizarre Trillion-Dollar Asteroid Worth More Than Our Planet Is Now Aligned With The Earth And Sun', *Forbes,* https://www.forbes.com/sites/jamiecartereurope/2020/12/05/a-bizarre-trillion-dollar-asteroid-worth-more-than-our-planet-is-now-aligned-with-the-earth-and-sun/ [01.03.2021].

Case, K. A. (2017), 'Insider Without: Journey across the Working-Class Academic Arc', *Journal of Working-Class Academics, 2(2)*, pp.16-35.

Chamberlain, K., Cain, T., Sheridan, J. and Dupuis, A, (2011), 'Pluralisms in Qualitative Research: From Multiple Methods to Integrated Methods', *Qualitative Research in Psychology, 8(2)*, pp.151-169.

Chapman, C. R., Morrison, D. and Zellner, B. (1975), 'Surface properties of asteroids: A synthesis of polarimetry, radiometry, and spectrophotometry', *Icarus*, *25(1)*, pp.104-130.

Childs, J. (2019), 'Greening the blue?: Corporate strategies for legitimizing deep sea mining', *Political Geography, 74*, 102060.

Childs, J. (2020), 'Performing 'blue degrowth'?: Critiquing seabed mining in Papua New Guinea through creative practice', *Sustainability Science, 15(1)*, pp.117-129.

Clark N. and Gunaratnam, Y. (2017), 'Earthing the *Anthropos*? From 'socializing the Anthropocene' to geologizing the social', *European Journal of Social Theory, 20(1)*, pp.146-163.

Clark, A. (2015), 'Afrofuturism on film: five of the best', *The Guardian*, https://www.theguardian.com/film/filmblog/2015/apr/02/afrofuturism-on-film-five-best-brooklyn-bamcinematek [18.01.2016].

Clark, N. (2005), 'Ex-orbitant Globality', *Theory, Culture and Society*, *22(5)*, pp.165-185.

Clark, N. (2011), *Inhuman Nature: sociable life on a dynamic planet*, London: Sage.

Clark, N. (2013), 'Geoengineering and geologic politics', *Environment and Planning A, 45(12)*, pp.2825-2832.

Clark, N. and Szerszynski, B. (2020), *Planetary Social Thought: The Anthropocene Challenge to the Social Sciences*, Cambridge: Polity Press.

Clark, N. and Yusoff, K. (2017), 'Geosocial Formations and the Anthropocene', *Theory, Culture and Society, 34(2-3)*, pp.3-23.

Clark, S. (2012), 'How dangerous is space debris?', *The Guardian*, https://www.theguardian.com/science/across-the-universe/2012/oct/04/astronomy-space [19.02.2018].

Clark, S. (2019), 'The greatest threat to life on Earth may come from space', *The Guardian*, https://www.theguardian.com/science/2019/aug/31/greatest-threat-to-life-on-earth-may-come-from-space-asteroids-satellite-debris [05.09.2019].

Cleland, D. (2017), 'Fishing for a Career: Alternative Livelihoods and the Hardheaded Art of Academic Failure', *Journal of Working-Class Studies, 2(2)*, pp.155-167.

CNEOS (2019), 'NEO Basics', *JPL*, https://cneos.jpl.nasa.gov/about/neo_groups.html [02.12.2019].

Cockell, C. and Horneck, G. (2004), 'A Planetary Park System for Mars', *Space Policy, 20(4)*, pp.291-295.

Cofield, C. (2016), 'Extraterrestrial Gold Rush: What's Next for the Space Mining Industry?', *space.com,* https://www.space.com/34774-whats-next-for-space-mining.html [18.03.2017].

Cole, D. M. (1963), '$50,000,000,000,000 from the Asteroids', *Space World, 4(2)*, pp.1-8.

Cole, D. M. and Cox, D. W. (1964), *Islands in Space: The Challenge of the Planetoids*, New York: Chilton Books.

Coleman, R. and Tutton, R. (2017), 'Introduction to Special Issue of *Sociological Review* on 'Futures in Question: Theories, Methods, Practices'', *The Sociological Review, 65(3)*, pp.440-447.

Collis, C. (2017), 'Territories beyond possession? Antarctica and Outer Space', *The Polar Journal, 7(2)*, pp.287-302.

Collis, C. and Graham, P. (2009), 'Political geographies of Mars: A history of Martian management', *Management & Organizational History, 4(3)*, pp.247-261.

Connolly, N. (2017), 'Introduction'. In: Connolly, N. (ed.), *Know Your Place: Essays on the Working Class by the Working Class*, Liverpool: Dead Ink Books.

Cope, M. (2003), 'Coding Transcripts and Diaries'. In: Clifford, N. J. and Valentine, G. (eds), *Key Methods in Geography*, London: Sage.

Cosslett, R. L. (2017), 'How sad that English-speaking parents fear their children being taught in Welsh', *The Guardian*, https://www.theguardian.com/education/2017/jun/22/sad-english-parents-afraid-children-taught-welsh [23.03.2020].

Cosslett, R. L. (2018a), 'Welsh-language pop culture is having a party – and everyone's invited', *The Guardian,* https://www.theguardian.com/commentisfree/2018/dec/12/welsh-language-party-spotify-culture [23.03.2020].

Cosslett, R. L. (2018b), 'Anti-Welsh bigotry is rife. It's just as well we're a tough people', *The Guardian*, https://www.theguardian.com/commentisfree/2018/mar/15/anti-welsh-bigotry-eddie-jones-england-brexit [23.03.2020].

Cosslett, R. L. (2019), 'Cymru am byth!* – How speaking Welsh became cool', *The Guardian*, https://www.theguardian.com/uk-news/2019/jun/13/welsh-speaking-bilingual-tv-thrillers-cool [23.03.2020].

Crang, M. (2005), 'Image-Reality'. In: Cloke, P., Crang, P. and Goodwin, M. (eds), *Introducing Human Geographies*, London: Hodder.

Crew, T. (2020), *Higher Education and Working-Class Academics: Precarity and Diversity in Academia*, London: Palgrave Macmillan.

Croal, P. and Darou, W. (2002), 'Canadian First Nations' experiences with international development'. In: Stillitoe, P., Bicker, A. and Pottier, J. (eds), *Participating in Development: Approaches to Indigenous Knowledge*, London: Routledge.

Crouch, M. and McKenzie, H. (2006), 'The logic of small samples in interview-based The logic of small samples in interview-based qualitative research', *Social Science Information, 45(4)*, pp.483-499.

Cruickshank, J. (2005), *Do Glaciers Listen?: Local Knowledge, Colonial Encounters, and Social Imagination*, Vancouver: University of British Columbia Press.

Currie-Patterson, N. and Watson, K. (2017), 'Conceptualizing Critical Friendship as a Protective Measure in Academia', *Journal of Working-Class Studies, 2(2)*, pp.67-81.

Czarniawska, B. and Hernes, T. (2005), 'Constructing macro actors according to ANT'. In: Czarniawska, B. and Hernes, T. (eds), *Actor-Network Theory and Organizing*, Abingdon: Marston Book Services.

Dąbrowska, I. (2017), 'The Role of *Cymraeg* in Shaping Welsh Identity', *Anglica: An International Journal of English Studies, 26(1)*, pp.131-147.

Daines, G. (2017), 'NASA's Journey to Mars', *NASA*, https://www.nasa.gov/content/nasas-journey-to-mars [02.12.2019].

Dalby, S. (2007), 'Anthropocene Geopolitics: Globalisation, Empire, Environment and Critique', *Geography Compass, 1(1)*, pp.103-118.

Darbyshire, P., MacDougall, C. and Schiller, W. (2005), 'Multiple methods in qualitative research with children: more insight or just more?', *Qualitative Research, 5(4)*, pp.417-436.

Davis, M. (1996), 'Cosmic Dancers On History's Stage? The Permanent Revolution In The Earth Sciences', *New Left Review, 217*, pp.48-84.

De Castro, E. V. (1998), 'Cosmological Deixis and Amerindian Perspectivism', *The Journal of the Royal Anthropological Institute, 4(3)*, pp.469-488.

de Laat, B. (2000), 'Scripts for the Future: Using Innovation Studies to Design Foresight Tools'. In: Brown, N., Rappert, B. and Webster, A. (eds), *Contested Futures: A sociology of prospective techno-science*, Aldershot: Ashgate.

de Seta, G. (2020), 'Sinofuturism as Inverse Orientalism: China's Future and the Denial of Coevalness', *SFRA, 50(2-3)*, pp.86-94.

Denzin, N. K. (1970), *The Research Act: A Theoretical Introduction to Sociological Methods*, Chicago: Aldine Publishing Company.

Dery, M. (1993), 'Black to the Future: Interviews with Samuel R. Delany, Greg Tate, and Tricia Rose', *The South Atlantic Quarterly, 92(4)*, pp.735-778.

Desjardins, J. (2016), 'There's Big Money to Be Made in Asteroid Mining', *Visual Capitalist,* https://www.visualcapitalist.com/theres-big-money-made-asteroid-mining/ [20.03.2017].

DeWalt, K. M. and DeWalt, B. R. (2011), *Participant Observation: a guide for fieldworkers*, Landham: Rowman & Littlefield.

Dews C. L. and Law, C. L. (1995), *This Fine Place So Far from Home: Voices of Academics from the Working Class,* Philadelphia: Temple University Press.

Diaz, E. (2018), 'Art and the New Space Age', *New Left Review, 112*, pp.144-160.

Dick, S. J. (2018), 'Space, Time and Aliens: The Role of Imagination in Outer Space'. In: Geppert, A. C. T. (ed.), *Imagining Outer Space: European Astroculture in the Twentieth Century*, London: Palgrave Macmillan.

Dickens, P. and Ormrod, J. S. (2007), 'Outer Space and Internal Nature: Towards a Sociology of the Universe', *Sociology, 41(4)*, pp.609-626.

Dickens, P. and Ormrod, J. S. (2009), *Cosmic Society: Towards a Sociology of the Universe*, London: Routledge.

Didi-Huberman, G. (2008), *Images in Spite of All: Four Photographs From Auschwitz*, Translated by S. B. Lillis, London: The University of Chicago Press.

Diprose, R. (2017), 'Speculative research, temporality and politics'. In: Wilkie, A., Savransky, M. and Rosengarten, M. (eds), *Speculative Research: The Lure of Possible Futures*, London: Routledge.

Doshi, P. D. (2016), 'Regulating The Final Frontier: Asteroid Mining and The Need For A New Regulatory Regime', *Notre Dame Journal of International & Comparative Law, 6(1)*, Article 15.

Dowling, R. (2005), 'Power, Subjectivity, and Ethics in Qualitative Research'. In: Hay, I. (ed.), *Qualitative Research in Human Geography*, Oxford: Oxford University Press.

Drake, F., Rummel, J. D. and Raup, D. M. (1993), 'Extraterrestrial Intelligence', *Science, 260(5107)*, pp.474-475.

Driver, F. (2005), 'Imaginative Geographies'. In: Cloke, P. Crang, P. and Goodwin, M. (eds), *Introducing Human Geographies*, London: Hodder.

Dudley-Flores, M. and Gangale, T. (2012), 'Forecasting the Political Economy of the Inner Solar System', *Astropolitics, 10(3)*, pp.183-233.

Dunbar, B. (2020), 'Microbes to Demonstrate Biomining of Asteroid Material Aboard Space Station', *NASA*, https://www.nasa.gov/mission_pages/station/research/news/bioasteroid-spacex-21 [21.02.2021].

Dunn, K. (2005), 'Interviewing'. In: Hay, I. (ed.), *Qualitative Research Methods in Human Geography*, Oxford: Oxford University Press.

Dunn, N. S. (2018), 'Urban Imaginaries and the Palimpsest of the Future'. In: Meissner, M. and Lindner, C. (eds), *The Routledge Companion to Urban Imaginaries*, London: Routledge.

Dunnett, O., Maclaren, A. S., Klinger, J., Lane, K. M. D., & Sage, D. (2019), 'Geographies of Outer Space: Progress and New Opportunities', *Progress in Human Geography, 43(2)*, pp.314-336.

Eisfeld, R. (2018), 'Projecting Landscapes of the Human Mind onto Another World: Changing Faces of an Imaginary World'. In: Geppert, A. C. T. (ed.), *Imagining Outer Space: European Astroculture in the Twentieth Century*, London: Palgrave Macmillan.

Ellis, E. G. (2017), 'How NASA Visualizes Stunning Worlds Without Really Seeing Them' *Wired*, https://www.wired.com/2017/04/nasa-visualizes-stunning-worlds-without-really-seeing/ [16.10.2020].

Elvis, M. and Milligan, T. (2019), 'How much of the Solar System should we leave as Wilderness?', *Acta Astronautica, 162*, pp.574-580.

Erickson, K. (2019), 'What is an asteroid?', *NASA: Space Place*, https://spaceplace.nasa.gov/asteroid/en/ [10.03.2020].

Erikson, K. (1994), *A New Species of Trouble: Explorations in Disaster, Trauma, and Community*, London: W. W. Norton & Company.

ESA (2019), 'In-Situ Resource Utilisation (ISRU) Demonstration Mission', https://exploration.esa.int/web/moon/-/60127-in-situ-resource-utilisation-demonstration-mission [accessed 07.10.2019].

ESA (2020), 'Spin-off technologies', https://www.esa.int/Science_Exploration/Space_Science/Spin-off_technologies [03.04.2020].

ESA (2021), 'Asteroid/Moon mining in-situ resource utilisation', *The European Space Agency*, https://www.esa.int/About_Us/Business_with_ESA/Global_Space_Economic_Forum/Asteroid_Moon_mining_in-situ_resource_utilisation [21.02.2021].

EV Stock Channel (2020), 'Elon Musk & SpaceX Asteroid Mining (Trillions to be made)', *YouTube*, https://www.youtube.com/watch?v=FjFirRnsgRo [01.03.2021].

Evans, G. (2013), 'Teach Welsh history to GCSE pupils in Wales, recommends review', *Wales Online*, https://www.walesonline.co.uk/news/wales-news/teach-welsh-history-gcse-pupils-3309972 [23.03.2020].

Eyles, J. (1988), 'Interpreting the Geographical World: Qualitative Approaches in Geographical Research'. In: Eyles, J. and Smith, D. M. (eds), *Qualitative Methods in Human Geography*, Cambridge: Polity Press.

Fairclough, N. (1992), *Discourse and Social Change*, London: Polity Press.

Fairclough, N. (2001), *Language and Power*, London: Longman.

Fairclough, N. (2003), *Analysing Discourse: Textual analysis for social research*, London: Routledge.

Fairclough, N. (2009), 'A Dialectical-Relational Approach to Critical Discourse Analysis in Social Research'. In: Wodak, R. and Meyer, M. (eds), *Methods in Critical Discourse Analysis*, London: Sage.

Fairclough, S. (2021), 'Coal tips: Almost 300 in Wales classed as 'high-risk'', *BBC News*, https://www.bbc.co.uk/news/uk-wales-56073459 [16.02.2021].

Fanon, F. (2001), *The Wretched of the Earth*, translated by Farrington, C., London: Penguin.

Farrell, P. B. (2013), 'Asteroid mining 2022 a $1 trillion bet for Earth', *MarketWatch*, https://www.marketwatch.com/story/asteroid-mining-2022-a-1-trillion-bet-for-earth-2013-01-08 [25.05.2016].

Feinman, M. (2014), 'Mining the Final Frontier: Keeping Earth's Asteroid Mining Ventures from Becoming the Next Gold Rush', *Journal of Technology, Law & Policy, XIV(Spring)*, pp.202-235.

Fickling, D. (2020), 'We're Never Going to Mine the Asteroid Belt', *Bloomberg*, https://www.bloomberg.com/opinion/articles/2020-12-21/space-mining-on-asteroids-is-never-going-to-happen [15.01.2021].

Finlay, L. (2002), 'Negotiating the swamp: the opportunity and challenge of reflexivity in research practice', *Qualitative Research, 2(2)*, 209-230.

Fisher, M. (2009), *Capitalist Realism: Is there no alternative?*, New Alresford: John Hunt Publishing.

Fladeland, L., Boley, A.C. and Byers, M. (2019), 'Meteoroid Stream Formation Due to the Extraction of Space Resources from Asteroids', Conference paper for the 1st International Orbital Debris Conference, December 9-12, available at: https://arxiv.org/ftp/arxiv/papers/1911/1911.12840.pdf

Fogg, M. J. (1998), 'Terraforming Mars: A review of current research', *Advances in Space Research, 22(3)*, pp.415-420.

Fogg, M. J. (2000), 'The ethical dimensions of space settlement', *Space Policy, 16*, pp.205-211.

Fox, S. J. (2016), 'SPACE: The race for mineral rights 'The sky is no longer the limit' Lessons from earth!', *Resources Policy, 49*, pp.165-178.

Fox, S. J. (2019), 'Policing mining: In outer-space greed and domination vs. peace and equity a governance for humanity!', *Resources Policy, 64*, 101517.

Frankenberg, R. (2002), 'Anthropologists: lions and/or foxes. An afterword'. In: Shore, C. and Nugent, S. (eds), *Elite Cultures: Anthropological perspectives*, London: Routledge.

Frith, R. (1992), 'A future for social anthropology?'. In: Wallman, S. (ed), *Contemporary Futures: Perspectives from Social Anthropology*, London: Routledge.

Gamu, J. K. and Dauvergne, P. (2018), 'The slow violence of corporate social responsibility: the case of mining in Peru', *Third World Quarterly, 39(5)*, pp.959-975.

Gandhi, L. (1998), *Postcolonial Theory: A Critical Introduction*, New York: Columbia University Press.

Garrett, D. (2016), 'The Improbable, Bold History of Space Concept Art', *Next*, https://howwegettonext.com/the-improbable-bold-history-of-space-concept-art-42c1fb1b6035 [16.10.2020].

Geels, F. W. and Smit, W. A. (2000), 'Lessons from Failed Technology Futures: Potholes in the Road to the Future'. In: Brown, N., Rappert, B. and Webster, A. (eds), *Contested Futures: A sociology of prospective techno-science*, Aldershot: Ashgate.

Geppert, A. C. T. (2018), 'European Astrofuturism, Cosmic Provincialism: Historicizing the Space Age'. In: Geppert, A. C. T. (ed.), *Imagining Outer Space: European Astroculture in the Twentieth Century*, London: Palgrave Macmillan.

Gilbert, P. R. (2017), 'The anthropology of financial intent', *Finance and Society, 3(1)*, pp.91-98.

Gilbert, P. R. (2020a), 'Speculating on sovereignty: 'money mining' and corporate foreign policy at the extractive industry frontier', *Economy and Society, 49(1)*, pp.16-44.

Gilbert, P. R. (2020b), 'Making critical materials valuable: Decarbonization, investment, and "political risk'. In: Bleicher, A. and Pehlken, A. (eds), *The Material Basis of Energy Transitions*, San Diego: Elsevier Science & Technology.

Gilbert, P. R. and Sklair, J. (2018), 'Introduction: Ethnographic engagements with global elites'. *Focaal – Journal of Global and Historical Anthropology, 81*, pp.1-15.

Gillibrand, P. (2019), 'In-depth: Will the new curriculum lead to more Welsh history being taught in schools?', *nation.cymru*, https://nation.cymru/news/in-depth-will-the-new-curriculum-lead-to-more-welsh-history-being-taught-in-schools/ [01.05.2019].

Giroux, H. A. (2014), *The Violence of Organized Forgetting: Thinking Beyond America's Disimagination Machine*, San Francisco: City Lights Books.

Glaze, L., Erickson, K., Davis, P. and Dunford, B. (2019), 'Ceres', *NASA Science: Solar System Exploration*, https://solarsystem.nasa.gov/planets/dwarf-planets/ceres/overview/ [20.08.2019].

Gov.uk (2018), 'One giant leap: Vertical launch spaceport to bring UK into new space age', *gov.*uk, https://www.gov.uk/government/news/one-giant-leap-vertical-launch-spaceport-to-bring-uk-into-new-space-age [15.07.2018].

Grady, M. (2017), 'Private companies are launching a new space race – here's what to expect', *The Conversation,* https://theconversation.com/private-companies-are-launching-a-new-space-race-heres-what-to-expect-80697 [11.11.2018].

Gregson, N. and Crang, M. (2010), 'Materiality and waste: Inorganic vitality in a networked world', *Environment and Planning A, 42(5)*, pp.1026–1032.

Griffin, A. (2020), 'Satellites to be Launched Into Space From Scotland After Approval of New Plan', *The Independent*, https://www.independent.co.uk/life-style/gadgets-and-tech/news/space-satellites-scotland-launch-uk-hie-orbit-a9678501.html [20.08.2020].

Guzmán, A. I. (2015), 'Indigenous Futurisms', *InVisible Culture: An Electronic Journal for Visual Culture, https://ivc.lib.rochester.edu/indigenous-futurisms/* [28.05.2016].

Gwenllian, S. (2020), 'It's Llyn Bochlwyd, not Lake Australia: Why we should protect our Welsh place names', *nation.cymru*, https://nation.cymru/opinion/its-llyn-bochlwyd-not-lake-australia-why-we-should-protect-our-welsh-place-names/ [04.08.2020].

Halbwachs, M. (1992), *On Collective Memory*, translated by Coser, L. A., Chicago: Chicago University Press.

Hall, L. (2020), 'Overview: In-Situ Resource Utilization', *NASA*, https://www.nasa.gov/isru/overview [21.02.2021].

Hall, S. (1992), 'The West and the rest: discourse and power'. In: Hall, S. and Gieben, B. (eds), *Formations of Modernity*, Cambridge: Polity Press.

Harrison, A. A. (2000), 'Slow track, fast track, and the "Galactic Club"', *Futures, 32,* pp.569-579.

Harrison, A. A. (2011), 'The Search for Extraterrestrial Intelligence: Astrocosiology and Cultural Aspects', *Astropolitics, 9(1)*, pp.63-83.

Hart, K. (2002), 'World society as an old regime'. In: Shore, C. and Nugent, S. (eds), *Elite Cultures: Anthropological perspectives*, London: Routledge.

Harvey, D. (1991), *The Condition of Postmodernity: An Enquiry into the Origins of Cultural Change*, Oxford: Blackwell.

Harvey, D. (2008), 'The Right to the City', *New Left Review, 53*, pp.23-40

Hassan, R. (2009), 'Crisis Time: Networks Acceleration and Politics within Late Capitalism', *Resetting Theory*, pp.1-21.

Hay, I. (2003), 'Ethical Practice in Geographical Research'. In: Clifford, N. J. and Valentine, G. (eds), *Key Methods in Geography*, London: Sage.

Hayward, T. (1997), 'Anthropocentrism: A Misunderstood Problem', *Environmental Ethics, 6(1)*, pp.49-63.

Haywood, G., Nilsson, J., Franklin, M., Gilbert, P., Krafve, L. J., Lindén, L., MacGillivray, M. and Meckin, R. (2014), 'Valuation Studies: A Collaborative Valuation in Practice', *Valuation Studies, 2(1)*, pp.71-85.

HDSF (2020), 'Terran', *Historical Dictionary of Science Fiction*, https://sfdictionary.com/view/127/terran [18.02.2021].

Healy, J. F. (1978), *Mining and Metallurgy in the Greek and Roman World*, London: Thames and Hudson.

Hearsey, C. M. and Pass, J. (2011), 'Astrosociology', *Astropolitics, 9(1)*, pp.1-5.

Hebditch, J. (2021), 'Scotland's first space launch as billion-dollar US company choose Shetland site for blast-off', https://www.dailyrecord.co.uk/news/scottish-news/scotlands-first-space-launch-billion-23474515 [10.02.2021].

Hechter, M. (1975), *Internal Colonialism: the Celtic fringe in British national development, 1536-1966*, Berkeley: University of California Press.

Helmreich, S. (2012), 'Extraterrestrial Realism', *Anthropological Quarterly, 85(4)*, pp.1125-1140.

Hennoste, T. (2012), 'Ethno-Futurism in Estonia', *International Yearbook of Futurism Studies II, 2(1)*, pp.253-285.

Hesse, B. (2002), 'Forgotten Like a Bad Dream: Atlantic Slavery and the Ethics of Postcolonial Slavery'. In: Goldberg, D. T. and Quayson, A. (eds.), *Relocating Postcolonialism*, Oxford: Blackwell Publishing.

Hickman, J. (2010), 'Viewpoint: Extraterrestrial National Territory and the International System', *Astropolitics, 8(1)*, pp. 62-71.

Hickman, J. (2012), 'Red Moon Rising', *Foreign Policy, 194*, pp.20-21.

Hird, M. J. (2013), 'Waste, Landfills, and an Environmental Ethics of Vulnerability', *Ethics and the Environment, 18(1),* pp.105-124.

Hird, M. J. and Zahara, A. (2017), 'The Arctic Wastes'. In: Grusin, R. (ed.), *Anthropocene Feminism* Minneapolis: University of Minnesota Press.

Hird, M.J. (2015) 'Waste, Environmental Politics and Dis/Engaged Publics', *Theory, Culture and Society, 34(2-3)*: pp.187-209.

Hird, M.J. (2016) 'Waste Legacies: Land, Waste, and Canada's DEW Line', *Northern Research*, *42,* pp.23-45. http://journals.sfu.ca/nr/index.php/nr/article/view/567 [20.02.2020]

Hird, M.J. (no date), 'Waste Flows', *The Discard Studies Compendium*, https://discardstudies.com/discard-studies-compendium/#Wasteflows [19.02.2020].

Holden, C. (1975), 'Futurism: Gaining a Toehold in Public Policy', *Science, 189*, pp.120-123.

Holstein, J. A. and Gabrium, J. F. (1997), 'Active Interviewing'. In: Silverman, D. (ed.), *Qualitative Research: Theory, Method and Practice*, London: Sage Publications.

Horton, J. and Kraftl, P. (2014), *Cultural Geographies: An Introduction*, London: Routledge.

Hörz, F., Hartung, J. B. and Gault, D. E. (1971), 'Micrometeorite craters on lunar rock surfaces', *Journal of Geophysical Research, 76(23)*, pp.5770-5798.

Hoskins, M. and Stoltz, J. (2005), 'Fear of offending: disclosing researcher discomfort when engaging in analysis', *Qualitative Research, 5(1),* pp.95-111.

Howell, E. (2018), 'Do We Need a Single International Language in Space?', *space.com*, https://www.space.com/40864-international-language-of-space.html [23.11.2018].

Hsu, J. (2010), 'Iran's Space Program: Lots of Talk, but a Chance to Shine', http://www.space.com/9499-iran-space-program-lots-talk-chance-shine.html [01.11.2015].

Hughes, S. (2019), 'The History of Wales – how is it represented in the curriculum?', *Senedd Research*, https://research.senedd.wales/research-articles/the-history-of-wales-how-is-it-represented-in-the-curriculum/ [23.03.2020].

Hurst, A. L., Griffin, T., and Vitale, A. (2017), ' Organizing Working-Class Academics: A Collective History', *Journal of Working-Class Studies, 2(2)*, pp.168-178.

Huston, S. (2002), 'Murray Bookchin on Mars!: The Production of Nature in Kim Stanley Robinson's Mars Trilogy'. In: Kitchin, R. and Kneale, J. (eds), *Lost in Space: Geographies of Science Fiction*, London: Continuum.

Italian Futurism (2014), 'The Founding and Manifesto of Futurism', http://www.italianfuturism.org/manifestos/foundingmanifesto/ [22.12.2015].

Jackson, P. (2001), 'Making sense of qualitative data'. IN: Limb, M. and Dwyer, C. (eds), *Qualitative Methodologies for Geographers: issues and debates*, London: Arnold.

Jamasmie, C. (2014), 'Asteroids mined for fuel to generate trillion dollar market, says firm', *mining.com*, https://www.mining.com/asteroids-mined-for-fuel-to-generate-trillion-dollar-market-says-firm-63951/ [25.05.2016].

Jamasmie, C. (2020), 'NASA finds rare metal asteroid worth more than global economy', *mining.com*, https://www.mining.com/nasa-finds-rare-metal-asteroid-worth-more-than-global-economy/ [30.10.2020].

James, N. and Busher, H. (2006), 'Credibility, authenticity and voice: dilemmas in online interviewing', *Qualitative Research, 6(3)*, pp.403-420.

James, N. and Busher, H. (2007), 'Ethical issues in online educational research: protecting privacy, establishing authenticity in email interviewing', *International Journal of Research & Method in Education, 30(1)*, pp.101-113

James, W. (2011), *Pragmatism and the meaning of truth*, Milton Keynes: Watchmakers.

Jameson, F. (1991), *Postmodernism: Or, the Cultural Logic of Late Capitalism*, London: Verso Books.

Janghorban, R., Roudsari, R. L. and Taghipour, A. (2014), 'Skype interviewing: The new generation of online synchronous interview in qualitative research', *International Journal of Qualitative Studies on Health and Well-being, 9(1)*, pp.1-3.

JAXA (2018), 'Hayabusa2 Information Fact Sheet', *JAXA*, https://www.hayabusa2.jaxa.jp/en/enjoy/material/factsheet/FactSheet_en_v2.31s.pdf [10.11.2018].

Jayanetti, C. (2020), 'The Black Lives Matter backlash is generating its own fake culture war', *The Guardian*, https://www.theguardian.com/commentisfree/2020/jul/06/black-lives-matter-backlash-fake-culture-war [06.07.2020].

Jervis, R. (1991), 'The Future of World Politics: Will It Resemble the Past?', *International Security, 16(3)*, pp.39-73.

Jessop, B. (2006), 'Spatial Fixes, Temporal Fixes and Spatio-Temporal Fixes'. In: Castree, N. and Gregory, D. (eds), *David Harvey: A Critical Reader*, London: John Wiley & Sons.

Johnson, E., Morehouse, H., Dalby, S., Lehman, J., Nelson, S., Rowan, R., Wakefield, S. and Yusoff, K. (2014), 'After the Anthropocene: Politics and geographic inquiry for a new epoch', *Progress in Human Geography, 38(3)*, pp.439-456.

Jones, C. H. (2021), 'Planet of People: A Timely Provocation'. In: Batakyte, M. (ed), *Lithuanian Space Agency: Annual Report No. 1*, Vilnius: Six Chairs Publishing.

Jones, C. H. and Whittle, R. (2021), 'Researcher self-care and caring in the research community', *Area, 53(2)*, pp.381-388.

Jones, M. E. (2018), 'Hacking into Future Wales: Haciaith and Cambrofuturism', *Planet Magazine*, https://www.planetmagazine.org.uk/planet-extra/Hacking-into-Future-Wales-Haciaith-and-Cambrofuturism [22.02.2018].

Jones, O. (2011), *Chavs: The Demonization of the Working Class*, London: Verso.

Kaku, M. (2011), *Physics of the Future: How Science Will Shape Human Destiny and Our Daily Lives by the Year 2100*, New York: Penguin.

Katz, C. (1994), 'Playing the Field: Questions of Fieldwork in Geography', *The Professional Geographer, 46(1)*, pp.67-72

Katz, E. and Oechsil, L. (1993), 'Moving beyond Anthropocentrism: Environmental Ethics, Development, and the Amazon', *Environmental Ethics, 15(1)*, pp.49-59.

Kawulich, B. B. (2005), 'Participant Observation as a Data Collection Method', *Qualitative Inquiry: Research, Archiving, and Reuse, 6(2)*, Article 43.

Kearnes, M. and van Dooren, T. (2017), 'Rethinking the Final Frontier: Cosmo-Logics and an Ethic of Interstellar Flourishing', *GeoHumanities, 3(2)*, pp.1-20.

Kelly, M. (2020), 'Scottish rocket launchpad gains planning approval', *Construction News*, https://www.constructionnews.co.uk/civils/scottish-rocket-launchpad-gains-planning-approval-20-08-2020/ [20.08.2020].

Kessler, D. J. and Cour-Palais, B. G. (1978), 'Collision frequency of artificial satellites: The creation of a debris belt', *Journal of Geophysical Research: Space Physics, 83(A6)*, pp.2637-2646.

Kessler, D. J., Johnson, N. L., Liou, J. -C. and Matney, M. (2010), 'The Kessler Syndrome: Implications to Future Space Operations', *AAS, 10-106*, accessible at: https://www.threecountrytrustedbroker.com/media/kesseler_syndrome.pdf

King, C. (2017), '#followfirstgenerationacademics', *Everyday Sociology*, https://www.everydaysociologyblog.com/2017/12/followfirstgenerationacademics.html [02.03.2018].

Kirby, D. (2010), 'The Future is Now: Diegetic Prototypes and the Role of Popular Films in Generating Real-world Technological Development', *Social Studies of Science, 40(1)*, pp.41-70.

Kirsch, S. (2014), *Mining Capitalism: The Relationship Between Corporations and Their Critics*, Oakland: University of California Press.

Kitchin, R. and Kneale, J. (2001), 'Science fiction of future fact? Exploring imaginative geographies of the new millennium', *Progress in Human Geography, 25(1)*, pp.19-35.

Kitchin, R. and Tate, N. J. (2000), *Conducting Research into Human Geography: theory, methodology & practice*, London: Prentice Hall.

Klinger, J. (2017), *Rare earth frontiers: from terrestrial subsoils to lunar landscapes*, New York: Cornell University Press.

Kneale, J. and Kitchin, R. (2002), 'Lost in Space'. In: Kitchin, R. and Kneale, J. (eds.), *Lost in Space: Geographies of Science Fiction*, London: Continuum.

Knox, P. and Agnew, J. (1994), *The Geography of the World Economy*, London: Routledge.

Kobayashi, A. (2001), 'Negotiating the personal and the political in critical qualitative research'. In: Limb, M. and Dwyer, C. (eds), *Qualitative Methodologies for Geographers: issues and debates*, London: Arnold.

Kolcheva, E. M. (2015), 'Formation of Ethno-Futurism at the Turn of the XX-XX1 Centuries', *Mediterranean Journal of Social Sciences, 6(3)*, pp. 231-236.

Lal, B. and Nightingale, E. (2014), 'Where is Space? And Why Does It Matter?', *Space Traffic Management Conference, 16*.

Lanier, J. (2013), *Who Owns the Future?*, London: Allen Lane.

Larkin, E. (2013), 'Benedetta and the creation of 'Second Futurism'', *Journal of Modern Italian Studies, 18(4)*, pp.445-465.

Latour, B. (2017), *Facing Gaia: Eight lectures on the new climactic regime*, translated by Porter, C., London: Polity.

Law, J. (2004), *After Method: Mess in Social Science Research*, London: Routledge.

Lawrence, A., Houghton, J., Thomas, J. and Weldon, P. (2014) 'Where Is the Evidence? Realising the Value of Grey Literature for Public Policy & Practice, A Discussion Paper', *Copyright, Fair Use, Scholarly Communication, etc.*, https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1162&context=scholcom [23.03.2020].

Lee, E. and Maynard, T. (2017), 'In Class, Sharing Class: Faculty Members from Low-Socioeconomic Status Backgrounds and Status Visibility', *Journal of Working-Class Studies, 2(2)*, pp.36-53.

LePan, N. (2019), 'More Than a Precious Metal: How Platinum Improves Our World', *Visual Capitalist*, https://www.visualcapitalist.com/how-platinum-improves-our-world/ [accessed 25.09.2019].

LeVine, R. A. and Campbell, D. T. (1972), *Ethnocentrism: Theories of Conflict, Ethnic Attitudes, and Group Behaviour*, London: John Wiley & Sons Ltd.

Lewis, A. (2021), ''Not fit for purpose': Review of laws around inspection and maintenance of Wales' coal tips', *nation.cymru*, https://nation.cymru/news/not-fit-for-purpose-review-of-laws-around-inspection-and-maintenance-of-wales-coal-tips/ [11.02.2021].

Lewis, B. (2019), 'History: Children 'must learn Wales' story' in school', *BBC News,* https://www.bbc.co.uk/news/uk-wales-50377446 [23.03.2020].

Li, T. M. (2014), 'What is land? Assembling a resource for global investment', *Transactions of the Institute of British Geographers, 39(4)*, pp.589-602.

Liboiron, M. (2018) 'Waste Colonialism' *Discard Studies*, https://discardstudies.com/2018/11/01/waste-colonialism/ [23.02.2019].

Lincoln, Y. S. and Guba, E. G. (1986), 'But is it rigorous? Trustworthiness and authenticity in naturalistic evaluation', *New Directions for Program Evaluation, 30*, pp.73-84.

Lloyd, D. (2020), 'Why the Senedd needs to look again at protecting Welsh place names', *nation.cymru*, https://nation.cymru/opinion/why-the-senedd-needs-to-look-again-at-protecting-welsh-place-names/ [02.07.2020].

Lockney, D. (2020), 'NASA Spinoff', *NASA*, https://spinoff.nasa.gov/ [03.04.2020].

Longhurst, R. (2003), 'Semi-structured Interviews and Focus Groups'. In: Clifford, N. J. and Valentine, G. (eds), *Key Methods in Geography*, London: Sage.

Loomba, A. (2005), *Colonialism/Postcolonialism*, London: Routledge.

Loomba, A., Kaul, S., Bunzl, M., Burton, A, and Esty, J. (2005), 'Beyond What? An Introduction'. In: Loomba, A., Kaul, S., Bunzl, M., Burton, A, and Esty, J. (eds.), *Postcolonial Studies and Beyond*, London: Duke University Press.

Lowenthal, D. (1992), 'The death of the future'. In: Wallman, S. (ed), *Contemporary Futures: Perspectives from Social Anthropology*, London: Routledge.

Lubrano, A. (2004), *Limbo*, Hoboken: John Wiley & Sons.

Luscombe, R. and Sample, I. (2020), 'SpaceX successfully launches Nasa astronauts into orbit', *The Guardian*, https://www.theguardian.com/science/2020/may/30/spacex-nasa-crewed-spaceflight-launch-dragon-capsule-elon-musk-trump [30.05.2020].

Lutz, C. A. (1990), 'Engendered emotion:gender, power, and the rhetoric of emotional control in American discourse'. In: Lutz, C. A. and Abu-Lughod, L. (eds), *Language and the politics of emotion*, Cambridge: Cambridge University Press.

Lynch, M. (2002), *Mining in World History*, London: Reaktion Books Ltd.

MacDonald, F. (2007), 'Anti-*Astropolitik* – outer space and the orbit of geography', *Progress in Human Geography, 31(5)*, pp.592-615.

MacKinnon, D. and Cumbers, A. (2011), *An Introduction to Economic Geography: Globalization, Uneven Development and Place*¸ Harlow: Prentice Hall.

Madoc-Jones, I., Parry, O. and Jones, D. (2013), 'The 'Chip Shop Welsh': Aspects of 'Welsh Speaking' Identity in Contemporary Wales', *Studies in Ethnicity & Nationalism, 13(3)*, pp.394-411.

Mahoney, E. (2019), 'In-Situ Resource Utilization', https://www.nasa.gov/isru [accessed 07.10.2019].

Major, L. E. and Machin, S. (2018), *Social Mobility: And Its Enemies*, London: Pelican.

Manning, H. P. (2002), 'English Money and Welsh Rocks: Divisions of Language and Divisions of Labor in Nineteenth-Century Welsh Slate Quarries', *Comparative Studies in Society and History, 44(3)*, pp.481-510.

Marchicelli, G. (1996), *Futurism and Fascism: The Politicization of Art and the Aestheticization of Politics, 1909-1944*, Michigan: UMI.

Mars One (2019), 'Mars One', *Mars One*, http://www.mars-one.com/ [10.11.2019].

Marx, K. (2015) [1887], *Capital: A Critique of Political Economy, Volume I*, translated by Moore, S. and Aveling, A., Moscow: Progress Publishers.

Mason, J. (1996), *Qualitative Researching*, London: Sage Publications.

Mason-Bish, H. (2019), 'The elite delusion: reflexivity, identity and positionality in qualitative research', *Qualitative Research, 19(3)*, pp.263-276.

Matloff, G., Johnson, L. and Bangs, C. (2014), *Harvesting Space for a Greener Earth*, New York: Springer.

Matson, Z. M. and Nunn, N. (2017), 'Space Infrastructure, Empire, And The Final Fronties: What The Mauna Kea Land Defenders Teach Us About Colonial Totality', *Society & Space Magazine*, https://www.societyandspace.org/forums/investigating-infrastructures [19.02.2021].

Mayr, M. (2008), 'Introduction: Power, discourse and institutions'. In: Mayr, A. (eds), *Language and Power: An Introduction to Institutional Discourse*, London: Continuum.

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

McClure, B. (2017), 'What Is An Astronomical Unit?', *EarthSky*, https://earthsky.org/space/what-is-the-astronomical-unit/ [15.06.2018].

McCurdy, H. E. (2011), *Space and the American Imagination*, Baltimore: The Johns Hopkins University Press.

McCurry, J. (2019), 'Japanese spacecraft 'bombs' asteroid in scientific mission', *The Guardian*, https://www.theguardian.com/science/2019/apr/05/japanese-spacecraft-bombs-asteroid-in-scientific-mission [05.04.2019].

McGeachan, C. and Philo, C. (2014), 'Words'. In: Lee, R., Castree, N., Kitchin, R., Lawson, V., Paasi, A., Philo, C., Radcliffe, S., Roberts, S. M. and Withers, C. W. J. (eds), *The SAGE Handbook of Human Geography: Volume 2*, London: Sage.

McKay, C. P., Toon, O. B. and Kasting, J. F. (1991), 'Making Mars habitable', *Nature, 352*, pp.489-496

McLean, I. and Johnes, M. (2000), *Aberfan: Government and Disasters*, Cardiff: Welsh Academic Press.

McLeod, J. (2010), *Beginning Postcolonialism*, Manchester: Manchester University Press.

McNeil, M., Arribas-Ayllon, M., Haran, J., Mackenzie, A. and Tutton, R. (2016), 'Conceptualizing Imaginaries of Science, Technology, and Society'. In: Felt, U., Fouche, R., Miller, C. A. and Smith-Doerr, L. (eds), *The Handbook of Science and Technology Studies*, London: The MIT Press.

McShane, K. (2007), 'Anthropocentrism vs. Nonanthropocentrism: Why Should We Care?', *Environmental Values, 16(2)*, pp.169-185.

Merck, C., Topcu, M. N. and Hirst, W. (2016), 'Collective mental time travel: Creating a shared future through our shared past', *Memory Studies, 9(3)*, pp.284-294.

Messeri, L. (2016), *Placing Outer Space: An Earthly Ethnography of Other Worlds,* Durham: Duke University Press.

Metuzals, J. and Hird, M.J. ' "The Disease that Knowledge Must Cure?" Sites of Uncertainty in Uranium mining in Arctic Development', Arctic Yearbook, pp. 1-17.

Miller J. and Glassner, B. (1997), 'The 'Inside' and the 'Outside': Finding Realities in Interviews'. In: Silverman, D. (ed.), *Qualitative Research: Theory, Method and Practice*, London: Sage Publications.

Miller, J. B. (1974), *Aberfan: A Disaster and Its Aftermath*, London: Constable.

Millington, N. and Lawhon, M. (2019), 'Geographies of waste: Conceptual vectors from the Global South', *Progress in Human Geography, 43(6)*, pp.1044-1063.

Minamore, B. (2018), 'Black to the future: afrofuturism hits the stage', *The Guardian*, https://www.theguardian.com/stage/2018/may/04/rachael-young-interview-nighclubbing-grace-jones-afrofuturism [04.11.2018].

Mistry, D. and Gopalaswamy, B. (2012), 'Ballistic Missiles and Space Launch Vehicles in Regional Powers', *Astropolitics, 10(2)*, pp.126-151.

Moore, S. A. (2012), 'Garbage matters: Concepts in new geographies of waste', *Progress in Human Geography, 36(6)*, pp.780-799.

Morris, S. (2019), 'Renaming the Welsh assembly: 'If we can say Dáil, why not Senedd?', *The Guardian*, https://www.theguardian.com/uk-news/2019/nov/08/renaming-the-welsh-assembly-if-we-can-say-dail-why-not-senedd [08.11.2019].

Moyser, G. and Wagstaffe, M. (1987), 'Studying elites: theoretical and methodological issues'. In: Moyser, G. and Wagstaffe, M. (eds), *Research Methods for Elite Studies*, London: Allen & Unwin.

Mughal, D. S. (2017), 'Navigating Space'. In: Connolly, N. (ed.), *Know Your Place: Essays on the Working Class by the Working Class*, Liverpool: Dead Ink Books.

Mukherjee, R. (2014), 'Escape from Terracentrism: Writing a Water History', *Indian Historical Review, 41(1)*, pp.87-101.

Mumford, L. (1934), *Technics and Civilization*, London: Routledge and Kegan Paul.

Murray, W. and Sample, I. (2021), 'Debris from Chinese rocket could hit Earth at weekend, says expert', *The Guardian*, https://www.theguardian.com/science/2021/may/06/chinese-rocket-falling-crash-to-earth-saturday-china-space-station-long-march-5b-us-space-command [06.05.2021].

Nader, L. (1972), 'Up the anthropologist: perspectives gained from studying up'. In: Hymes, D. (ed.), *Reinventing Anthropology*, New York: Pantheon Books.

Nef, J. (1964), *The Conquest of the Material World*, London: The University of Chicago Press.

Nelson, A. (2002), 'Introduction: Future Texts', *Social Text, 20(2(71))*, pp.1-15.

Newlove-Erikksen, L. and Erikksen, J. (2013), 'Governance Beyond the Global: Who Controls the Extraterrestrial?', *Globalizations, 10(2)*, pp.277-292.

Nixon, R. (2011), *Slow Violence and the Environmentalism of the Poor*, Cambridge: Harvard University Press.

Norton, B. G. (1984), 'Environmental Ethics and Weak Anthropocentrism', *Environmental Ethics, 6(2)*, pp.131-148.

Nunan, D. (1993), *Introducing Discourse Analysis*, London: Penguin.

O'Callaghan, J. (2020), 'What is space junk and why is it a problem?', *Natural History Museum*, https://www.nhm.ac.uk/discover/what-is-space-junk-and-why-is-it-a-problem.html [23.11.2020].

O'Neill, D. (2017), '"Not Working Class Anymore"', *Britain Has Class*, https://www.britainhasclass.org/post/you-re-not-working-class-anymore [24.11.2017].

O'Neill, G. K. (1976), *The High Frontier: Human Colonies in Space*, New York: William Morrow & Company.

Olah, N. (2019), ''Impostor syndrome' is a pseudo-medical name for a class problem', *The Guardian*, https://www.theguardian.com/commentisfree/2019/oct/16/impostor-syndrome-class-unfairness [16.10.2019].

Oppermann, E., Walker, G. and Brearley, M. (2020), 'Assembling a thermal rhythmanalysis: energetic flows, heat stress and polyrhythmic interactions in the context of climate change', *Geoforum, 108*, pp.275-285.

Ormrod, J. and Dickens, P. (2019), 'Space tourism, capital, and identity'. In: Cohen, E. and Spector, S. (eds), *Space Tourism: The Elusive Dream*, London: Emerald Publishing.

Owen, T. (2018), 'Fear 'history is lost when Welsh place names are changed'', *BBC News*, https://www.bbc.co.uk/news/uk-wales-44481950 [01.06.2018].

Pandya, J. (2019), 'The Race To Mine Space', *Forbes,* https://www.forbes.com/sites/cognitiveworld/2019/05/13/the-race-to-mine-space/ [13.05.2019].

Pankhurst, A. and Jeevendrampillai, D. (2020), 'Towards an anthropology of gravity: Emotion and embodiment in microgravity environments', *Emotion, Space and Society, 35*, 100680.

Parikka, J. (2018), 'Middle East and other futurisms: imaginary temporalities in contemporary art and visual culture', *Culture, Theory and Critique, 59(1)*, pp.40-58.

Parry, B. (2002), 'Directions and Dead Ends in Postcolonial Studies'. In: Goldberg, D. T. and Quayson, A. (eds), *Relocating Postcolonialism*, Oxford: Blackwell Publishing.

Parsons, R., Lacey, J. and Moffat, K. (2014), 'Maintaining legitimacy of a contested practice: How the minerals industry understands its 'social licence to operate'', *Resources Policy, 41,* pp.83-90.

Pass, J. (2006), 'Astrosociology as the Missing Perspective', *Astropolitics, 4(1)*, pp.85-99.

Pass, J. (2011), 'Examining the Definition of Astrosociology', *Astropolitics, 9(1)*, pp.6-27.

Patai, D. (1994), 'When method becomes power'. In: Gitlen, A. (ed.), *Power and method*, New York: Routledge.

Patel, R. and Moore, J. W. (2017), *A History of the world in seven cheap things : a guide to capitalism, nature and the future of the planet*, Oakland: University of California Press.

Perloff, M. (2003), *The Futurist Moment: Avant-Garde, Avant Guerre, and the Language of Rupture*, London: The University of Chicago Press.

Phillips, C. R. and Hoffman, R. K. (1960), 'Sterilization of Interplanetary Vehicles: Earthly organisms can be kept from contaminating the moon and planets, but careful planning will be required', *Science, 132(3433)*, pp.991-995.

Pillow, W. (2003), 'Confession, catharsis, or cure? Rethinking the uses of reflexivity as methodological power in qualitative research', *International Journal of Qualitative Studies in Research, 16(2)*, pp.175-196.

Poo, A. (2012), 'Movement Futurism', *The American Prospect, 23(8)*, p.25.

Posey, D. (2002), 'Upsetting the sacred balance: can the study of indigenous knowledge reflect cosmic connectedness?'. In: Stillitoe, P., Bicker, A. and Pottier, J. (eds), *Participating in Development: Approaches to Indigenous Knowledge*, London: Routledge.

Potter, R. B., Binns, T., Elliot, J. A. and Smith, D. (2008), *Geographies of Development: An Introduction to Development Studies*, Harlow: Prentice Hall.

Povinelli, E. A. (1995), 'Do Rocks Listen? The Cultural Politics of Apprehending Australian Aboriginal Labor', *American Anthropologist, 97(3)*, pp.505-518.

Price, A. (2018), *Wales: The First & Final Colony*, Talybont: Y Lolfa.

Price, I. (2000), 'Diameter of a Grain of Sand', *The Physics Factbook: An encyclopaedia of scientific essays*, https://hypertextbook.com/facts/2000/IlanaPrice.shtml [15.01.2020].

Purcell, C. (2017), 'A Working Class Academic', *Britain Has Class*, https://www.britainhasclass.org/post/an-account-of-a-working-class-academic [24.11.2017].

Quan, H. L. T. (2017), '"It's Hard to Stop Rebels That Time Travel": Democratic Living and the Radical Reimagining of Old Worlds'. In: Johnson, G. T. and Lubin, A. (eds.), *Futures of Black Radicalism*, London: Verso.

Rabie, P. (2021), 'James Webb Space Telescope: Why Dirt May Ruin Our Best View of Aliens', *Inverse*, https://www.inverse.com/science/james-webb-space-telescope-flaw [23.06.2021].

Radlof, J. G. (1823) [2009], *The Shattering of the Great Planets Hesperus and Phaethon: and the Ensuing Destructions and Floods of Earth*, translated by de Grazia, A., London: Metron Publications.

Raymond, S. N. and Izidoro, a. (2017), 'The empty primordial asteroid belt', *Science Advances, 3(9)*, e1701138.

Redclift, M. R. (2006), *Frontiers: Histories of Civil Society and Nature*, London: The MIT Press.

Redfield, P. (2000), *Space in the Tropics: From Convicts to Rockets in French Guiana*, Oakland: University of California Press.

Rediker, M. (2015), *Outlaws of the Atlantic: Sailors, Pirates, and Motley Crews in the Age of Sail*, Boston: Beacon Press.

Redmond, S. (2016), 'The Whiteness of Cinematic Outer Space'. In: Ormrod, J. S. and Dickens, P. (eds), *The Palgrave Handbook of Society, Culture and Outer Space*, London: Palgrave Macmillan.

Reger, J. (2001), 'Emotions, objectivity and voice : An analysis of a "failed" participant observation', *Womens Studies International Forum, 24(5)*, pp.605-616

Reno, J. (2015), 'Waste and Waste Management', *The Annual Review of Anthropology, 44*, pp.557-572.

Reyes, J. A. D. (2016), *Mining Shareholder Value: Financialisation, Extraction, and the Geography of Gold Mining*, Thesis: University of Manchester.

Reynolds, E. (2020), 'First-Generation University Students Are At Greater Risk Of Experiencing Imposter Syndrome', *British Psychological Society: Research Digest*, https://digest.bps.org.uk/2020/01/09/first-generation-university-students-are-at-greater-risk-of-experiencing-imposter-syndrome/?fbclid=IwAR0fZ8EIsu49F5JB5JCy-TEg5owoVR9rUp5nxuFXfWUcFvmVqBv1lRa2wTA [09.01.2020].

Richardson, T. and Weszkalnys, G. (2014), 'Introduction: Resource Materialities', *Anthropological Quarterly, 87(1)*, pp.5-30.

Rincon, P. (2013), 'New venture 'to mine asteroids'', https://www.bbc.co.uk/news/science-environment-21144769 [23.01.2013].

Roberts, A. (2019), 'From Black Panther to Tade Thompson: why Afrofuturism is taking over sci-fi', *The Guardian*, https://www.theguardian.com/books/2019/jul/26/tade-thompson-afrofuturism-black-panther-sci-fi-sf-african-fiction [26.07.2019].

Robinson, G. M. (1998), *Methods and Techniques in Human Geography*, Chichester: John Wiley & Sons.

Rose, H. (2000), 'Science Fiction's Memory of the Future'. In: Brown, N., Rappert, B. and Webster, A. (eds), *Contested Futures: A sociology of prospective techno-science*, Aldershot: Ashgate.

Rosenberg, D. V. (1990), 'Language in the discourse of the emotions'. In: Lutz, C. A. and Abu-Lughod, L. (eds), *Language and the politics of emotion*, Cambridge: Cambridge University Press.

Rourke, A. (2021), ''Out-of-control' Chinese rocket falling to Earth could partially survive re-entry', *The Guardian*, https://www.theguardian.com/science/2021/may/04/out-of-control-chinese-rocket-tumbling-to-earth [04.05.2021].

Rowan, R. (2015), 'Extinction as usual?: Geo-social futures and left optimism', *E-flux Journal,* https://www.e-flux.com/journal/65/336413/extinction-as-usual-geo-social-futures-and-left-optimism/ [13.09.2018].

Rye, J. (1972), *Futurism*, London: Studio Vista.

Sample, I. (2014), 'Asteroid strike warnings build towards campaigners' big day of rock', *The Guardian*, https://www.theguardian.com/science/2014/dec/03/asteroid-strike-warning-campaigners-day-of-rock-awareness-day [05.09.2019].

Sanz-Menéndez, L. and Cabello, C. (2000), 'Expectations and Learning as Principles for Shaping the Future'. In: Brown, N., Rappert, B. and Webster, A. (eds), *Contested Futures: A sociology of prospective techno-science*, Aldershot: Ashgate.

Saplakoglu, Y. (2019), 'How Astronomers Missed the Massive Asteroid That Just Whizzed Past Earth', *Live Science*, https://www.livescience.com/66043-giant-asteroid-flyby-surprises-astronomers.html [01.08.2019].

Sarpong, J. (2017), *Diversify: How to challenge inequality and why we should*, London: HQ.

Savransky, M., Wilkie, A. and Rosengarten, M. (2017), 'The lure of possible futures: On speculative research'. In: Wilkie, A., Savransku, M. and Rosengarten, M. (eds), *Speculative Research: The Lure of Possible Futures*, London: Routledge.

Sayej, N. (2018), 'Beyond Black Panther: afrofuturism takes flight at Chicago museum', *The Guardian*, https://www.theguardian.com/artanddesign/2018/apr/10/afrofuturism-exhibition-in-their-own-form-museum-contemporary-photography-chicago [12.04.2018].

Schwartz, M. S. and Schwartz, C. G. (1955), 'Problems in Participant Observation', *American Journal of Sociology, 60(4)*, pp.343-353.

Scoles, S. (2016), 'How Space Scientists Turn Exoplanets Into Places We Can 'See'', *Wired*, https://www.wired.com/2016/09/space-scientists-turn-exoplanets-places-can-see/ [16.10.2020].

Segrott, J. (2001), 'Language, geography and identity: The case of the Welsh in London', *Social & Cultural Geography, 2(3)*, pp.281-296.

Shore, C. (2002), 'Introduction: towards an anthropology of elites'. In: Shore, C. and Nugent, S. (eds), *Elite Cultures: Anthropological perspectives*, London: Routledge.

Silverman, D. (1985), *Qualitative Methodology and Sociology*, Aldershot: Gower Publishing.

Silverman, D. (2003), *Doing Qualitative Research: A Practical Handbook*, London: Sage.

Silverman, D. (2011), *Interpreting Qualitative Data: A Guide to the Principles of Qualitative Research*, London: Sage.

Silverman, D. (2013), *Doing Qualitative Research*, London: Sage.

Skelton, T. (2001), 'Cross-cultural research: issues of power, positionality and 'race''. In: Limb, M. and Dwyer, C. (eds), *Qualitative Methodologies for Geographers: issues and debates*, London: Arnold.

Skymining (2019), ''Skymining', https://skymining.com/en/skymining-en/ [30.10.2020].

Smiles, D. (2020), 'The Settler Logics of (Outer) Space', *Society & Space Magazine*, https://www.societyandspace.org/articles/the-settler-logics-of-outer-space [31.10.2020].

Smith, L. T. (1999), *Decolonizing Methodologies: Research and Indigenous Peoples,* London: Zed Books Ltd.

Smolarek, B. B. (2019), 'The Hidden Challenges for Successful First-Generation Ph.D.s', *Inside Higher Ed*, https://www.insidehighered.com/advice/2019/10/09/first-generation-phd-student-describes-her-struggles-opinion [09.10.2019].

Sojoyner, D. M. (2017), 'Dissonance in Time: (Un)Making and (Re)Mapping of Blackness'. In: Johnson, G. T. and Lubin, A. (eds), *Futures of Black Radicalism*, London: Verso.

Sommariva, A. (2014), 'Motivations Behind Interstellar Exploration and Colonization', *Astropolitics, 12(1)*, pp.82-94.

Sommariva, A. (2015), Rationale, Strategies, and Economics for Exploration and Mining of Asteroids', *Astropolitics, 13(1)*, pp.25-42.

SpaceX (2021), 'Mars & Beyond: The Road to Making Humanity Multiplanetary', *SpaceX*, https://www.spacex.com/human-spaceflight/mars/ [03.04.2021].

Spennemann, D. H. R. (2004), 'The ethics of treading on Neil Armstrong's footprints', *Space Policy, 20*, pp.279-290.

Spradley, J. P. (1980), *Participant Observation*, New York: Holt, Rinehart and Winston.

Squire, R., Mould, O. and Adey, P. (2021), 'The Final Frontier? The Enclosure of a Commons of Outer Space', *Society & Space Magazine*, https://www.societyandspace.org/forums/the-final-frontier-the-enclosure-of-a-commons-of-outer-space [30.05.2021].

Stableford, B. and Langford, D. (2018), 'Asteroids', *The Encyclopedia of Science Fiction*, http://www.sf-encyclopedia.com/entry/asteroids [15.02.2018].

Steinberg, P. E. (2018), 'Editorial: The ocean as frontier', International Social Science Journal, 68(299-230), pp.237-240.

Stengers, I. (1997), *Power and Invention: Situating Science*, London: University of Minnesota Press.

Stengers, I. (2000), *The Invention of Modern Science*, London: University of Minnesota Press.

Stingl, A. I. (2016), '"Give Me Sight Beyond Sight": Thinking With Science Fiction as Thinking (Together) With (Others)', *Bulletin of Science, Technology & Society, 36(1)*, pp.3-27.

Stockwell, S. (2020), 'Legal 'Black Holes' in Outer Space: The Regulation of Private Space Companies', *E-International Relations*, https://www.e-ir.info/2020/07/20/legal-black-holes-in-outer-space-the-regulation-of-private-space-companies/ [27.07.2020].

Straus, A. L. (1996), *Qualitative Analysis for Social Scientists*, Cambridge: Cambridge University Press.

SummerM. and Trefil, J. (2017), *Exoplanets: Diamond Worlds, Super Earths, Pulsar Planets, and the New Search for Life Beyond Our Solar System*, Washington D. C.: Smithsonian Books.

Szerszynski, B. (unpublished), 'Acting ahead of the future: towards an embodied, cognitive, social theory of anticipation'.

Szerszynski, B. (2018), 'A planetary turn for the social sciences?'. In: Jensen, O. B., Kesserling, S. and Sheller, M. (eds), *Mobilities and Complexities*, London: Taylor and Francis.

Szerszynski, B. (2019), 'Epilogue: Indigenous worlds and planetary futures'. In: Bold, R. (ed.), *Indigenous Perceptions of the End of the World: Creating a Cosmopolitics of Change*, London: Plagrave Macmillan.

Szpunar, P. M. and Szpunar, K. K. (2016), 'Collective future thought: Concept, function, and implications for collective memory studies', *Memory Studies, 9(4)*, pp.376-389.

Taylor, A. R. E. (2020), 'Space Weather as a Threat to Critical Infrastructure', *Roadsides, 3*.

Taylor, P. J. (2009), 'Time: From Hegemonic Change to Everyday Life'. In: Clifford, N. J., Holloway, S. L., Rice, S. P. and Valentine, G. (eds), *Key Concepts in Geography*, London: Sage.

Taylor-Stone, C. (2014), 'Afrofuturism: where space, pyramids and politics collide', *The Guardian*, https://www.theguardian.com/science/political-science/2014/jan/07/afrofuturism-where-space-pyramids-and-politics-collide [18.01.2016].

Tholen, D. J. (1989), 'Asteroid taxonomic classifications'. In: Binzel, R. P., Gehrels, T. and Matthews, M. S. (eds), *Asteroids II*, New York: University of Arizona Press.

Thrasher, S. W. (2015), 'Afrofuturism: reimagining science and the future from a black perspective', *The Guardian*, https://www.theguardian.com/culture/2015/dec/07/afrofuturism-black-identity-future-science-technology [18.01.2016].

Triscott, N. (2016), 'Transmissions from the Noosphere: Contemporary Art and Outer Space'. In: Ormrod, J. S. and Dickens, P. (eds), *The Palgrave Handbook of Society, Culture and Outer Space*, London: Palgrave Macmillan.

Tsing, A. L. (2003), 'Natural Resources and Capitalist Frontiers', *Economic and Political Weekly, 38(48)*, pp.5100-5106.

Tutton, R. (2017), 'Wicked futures: Meaning, matter and the sociology of the future', *The Sociological Review, 65(3)*, pp.478-492.

Tyfield, D. (2017), *Liberalism 2.0 and the Rise of China: Global Crisis, Innovation and Urban Mobility*, London: Routledge.

Urry, J. (2016), *What is the Future?*, Cambridge: Polity Press.

Valdivia ,G. (2008), 'Governing relations between people and things: Citizenship, territory, and the political economy of petroleum in Ecuador', *Political Geography, 27*, pp.456-477.

Valentine, D. (2012), 'Exit Strategy: Profit, Cosmology, and the Future of Humans in Space', *Anthropological Quarterly, 85(4)*, pp.1045-1068.

Valentine, D. (2017), 'Gravity fixes: Habituating to the human on Mars and Island Three', *Journal of Ethnographic Theory, 7(3)*, pp.185-209.

Valentine, G. (1997), 'Tell me about . . .: using interviews as a research methodology'. In: Flowerdew, R. and Martin, D. (eds), *Methods in Human Geography: a guide for students doing research projects*, Harlow: Longman.

van Lente, H. (2000), 'Forceful Futures: From Promise to Requirement'. In: Brown, N., Rappert, B. and Webster, A. (eds), *Contested Futures: A sociology of prospective techno-science*, Aldershot: Ashgate.

van Lente, H. (2012), 'Navigating foresight in a sea of expectations: lessons from the sociology of expectations', *Technology Analysis & Strategic Management, 24(8)*, pp.769-782.

van Wyck, P. C. (2005), *Signs of Danger: Waste, Trauma, and Nuclear Threat*, London: University of Minnesota Press.

Vedda, J. A. (2008), 'Challenges to the Sustainability of Space Exploration', *Astropolitics, 6(1)*, pp.22-49.

Vergès, F. (2017), 'Racial Capitalocene'. In: Johnson, G. T. and Lubin, A. (eds), *Futures of Black Radicalism*, London: Verso.

Vossen, E. (2017), 'Publish AND Perish: On Publishing, Precarity and Poverty in Academia', *Journal of Working-Class Studies, 2(2)*, pp.121-135.

Walker, G. (2021), *Energy and Rhythm: Rhythmanalysis for a Low Carbon Future*, London: Rowman & Littlefield Publishers.

Walker, G., Booker, D. and Young, P. (2020), 'Breathing in the polyrhythmic city: a spatiotemporal, rhythmanalytic account of urban air pollution and its inequalities', *Environment & Planning C: Politics and Space,* E-pub ahead of print.

Wall, M. (2015), 'India's 1st Mars Mission Celebrates One Year at Red Planet', http://www.space.com/30633-india-mars-orbiter-mission-anniversary.html [01.11.2015].

Warnock, D. M. (2016), 'Paradise Lost? Patterns and Precarity in Working-Class Academic Narratives', *Journal of Working-Class Studies, 1(1)*, pp.28-44.

White, G. M. (1990), 'Moral discourse and the rhetoric of emotions'. In: Lutz, C. A. and Abu-Lughod, L. (eds), *Language and the politics of emotion*, Cambridge: Cambridge University Press.

Whitehead, A. N. (1967), *Adventures of ideas*, New York: Free Press.

Wieszczycka, K. (2018), 'Wastes generated by mineral extraction industries', *Physical Sciences Reviews, 3(6)*, 20180026.

Wilkes, J. and Hird, M.J. (2019) 'Colonial Ideologies of Waste: Implications for Land and Life', *Europe Now*, https://www.europenowjournal.org/2019/05/06/colonial-ideologies-of-waste-implications-for-land-and-life/ [18.02.2020].

Williams, M. (2016), 'How Far is the Asteroid Belt from Earth?', *Universe Today* https://www.universetoday.com/130136/far-asteroid-belt-earth/ [17.09.2019].

Wilson, J. (2018), 'What is NASA's Asteroid Redirect Mission, https://www.nasa.gov/content/what-is-nasa-s-asteroid-redirect-mission [05.09.2019].

Wilson, S. and Taipua, D. (2015), 'Aotearoa Futurism part one: Space Maori and Astronesians', http://www.radionz.co.nz/national/programmes/nat-music/audio/201782605/aotearoa-futurism-part-one [06.01.2016].

Winchester, H. P. M. (2005), 'Qualitative Research and its Place in Human Geography'. In: Hay, I. (ed.), *Qualitative Research Methods in Human Geography*, Oxford: Oxford University Press.

Wolgemuth, J. R. and Donohue, R. (2006), 'Toward an Inquiry of Discomfort: Guiding Transformation in "Emancipatory" Narrative Research', *Qualitative Inquiry, 12(5)*, pp.1012-1021.

Woo, B. (2017), 'The Invisible Bag of Holding: Whiteness and Media Fandom'. In: Click, M. A. and Scott, S. (eds), *The Routledge Companion to Media Fandom*, London: Routledge.

Wood, E. M. (2017), *The Origin of Capitalism: A Longer View*, London: Verso.

Worden, S. P. and Sponable, J. (2006), 'Access to Space: A Strategy for the Twenty-First Century', *Astropolitics, 4(1)*, pp.69-83.

Yaszek, L. (2006), 'Afrofuturism, science fiction, and the history of the future', *Socialism and Democracy, 20(3)*, pp.41-60.

Young, M. J. (1987), '"Pity the Indians of Outer Space": Native American Views of the Space Programme', *Western Folklore, 46(4)*, pp.269-279.

Young, R. J. C. (2001), *Postcolonialism: An Historical Introduction*, London: Blackwell Publishing.

Yuhas, A. (2014), 'Rosetta: what went right with Philae, what went wrong and how it can be fixed', *The Guardian*, https://www.theguardian.com/science/2014/nov/13/rosetta-philae-comet-mission-what-went-right-what-went-wrong-and-how-it-can-be-fixed [17.09.2019].

Yuhas, A. (2016), 'Earth woefully unprepared for surprise comet or asteroid, Nasa scientist warns', *The Guardian*, https://www.theguardian.com/science/2016/dec/13/space-asteroid-comet-nasa-rocket [05.09.2019].

Yusoff, K. (2013a), 'Geologic life: prehistory, climate, futures in the Anthropocene', *Environment and Planning D: Society and Space, 31(5)*, pp.779 – 795.

Yusoff, K. (2013b), 'The geoengine: geoengineering and the geopolitics of planetary modification', *Environment and Planning A: international journal of urban and regional research, 45(12),* pp.2799 - 2808.

Yusoff, K. (2015), 'Anthropogenesis: Origins and Endings in the Anthropocene', *Theory, Culture and Society: explorations in critical social science, 33(2)*, pp.3-28.

Yusoff, K. (2017), 'Geosocial Strata', *Theory, Culture and Society, 34(2-3)*, pp.105–127.

Yusoff, K. (2018), *A Billion Black Anthropocenes or None,* Minneapolis: The University of Minnesota Press.

Appendix 1: List of SF Texts, Movies, Television, and Videogames Used

Books, Novels, and Short Stories

2312 by Kim Stanley Robinson (2012)

A Torrent of Faces by James Blish and Norman L. Knight (1967)

A Voyage to the Moon by George Tucker (1828)

Asteroid Pirates by Royal W. Heckman (1938)

Conservation of Shadows by Yoon Ha Lee (2013) – a collection of 16 stories

Edison's Conquest of Mars by Garrett P. Serviss (1898)

Eight Keys to Eden by Mark Clifton (1960)

Garbage World by Charles Platt (1967

Lucky Star and the Pirates of the Asteroid by Isaac Asimov (1953)

Marooned Off Vesta by Isaac Asimov (1939)

Midnight Robber by Nalo Hopkinson (2000)

Mindscape by Andrea Hairston (2006)

Misfit by Robert A. Heinlein (1939)

Reply Paid by Gerald Heard (1942)

Seetee Shock by Jack Williamson (1949)

The Asteroid of Gold by Clifford D. Simak (1932)

The Crack of Doom by Robert Comie (1895)

The Golden Planetoid by Stanton A. Coblentz (1935)

So Long Been Dreaming: Postcolonial Science Fiction & Fantasy edited by Nalo Hopkinson and Uppinder Mehan (2011), includes the short stories:

- *Deep End* by Nisi Shawl
- *Griots of the Galaxy* by Andrea Hairston
- *Toot Sweet Matricia* by Suzette Mayr
- *Rachel* by Larissa Lai
- *Terminal Avenue* by Eden Robinson
- *When Scarabs Multiply* by Nnedi Okorafor-Mbachu
- *Delhi* by Vandana Singh
- *Panopte's Eye* by Tamai Kobayashi
- *The Grassdreaming Tree* by Sheree R. Thomas
- *The Blue Road: A Fairy Tale* by Wayde Compton
- *The Forgotten Ones* by Karin Lowachee
- *Native Aliens* by Greg van Eekhout
- *Refugees* by Celu Amberstone
- *Trade Winds* by devorah major
- *Lingua Franca* by Carole McDonnell
- *Out of Sync* by Ven Begamudré
- *The Living Roots* by Opal Palmer Adisa
- *Journey Into the Vortex* by Maya Khankhoje
- *Necahual* by Tobias S. Buckell

Television and Film

Alien (1979)

Armageddon (1998)

Deep Impact (1998)

Dr Strangelove or: How I Learned to Stop Worrying and Love the Bomb (1964)

Elysium (2013)

Greenland (2020)

Impact (2009)

Meteor (1979)

Red Dwarf (1988-present)

Rick and Morty (2013-present)

Star Wars (1977)

Star Wars: Empire Strikes Back (1980)

The Chronicles of Riddick: Pitch Black (2000)

The Day the Sky Exploded (1958)

The Expanse (2015-present)

Videogames

EVE Online (2013)

No Man's Sky (2016)