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# ESSAYS IN SPACE ETHICS

Oskari Sivula

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UNIVERSITY OF TURKU

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ABSTRACT

In five articles and an introduction, this dissertation contributes to the emerging field of space ethics by exploring questions about environmental ethics in outer space, considered from a long-term perspective.

In particular, it examines directed panspermia, which refers to the deliberate introduction of rudimentary lifeforms onto uninhabited celestial bodies in order to initiate biospheres beyond Earth. Such an act, if possible, could constitute humanity's most significant biological cosmic footprint.

The central claims of this study are the following. Given uncertainty surrounding life beyond Earth, and given the fact that life on Earth will eventually end, we have compelling reasons to use directed panspermia as a way to safeguard life originating on Earth—either to efficiently promote value, or to conserve what is valuable. But there are major objections to this proposal, including the risks of interfering with potential indigenous life at a target planet and propagating suffering if, over time, sentient beings arise on the seeded planet. The objections' strength depends on unresolved empirical and moral uncertainties. As a result, directed panspermia may turn out either extremely good or extremely bad. In light of this difficult choice, I ague for caution regarding biological contamination.

Along the way I also consider two other objections to directed panspermia: appeals to the "unnaturalness" of planetary seeding, and the values of abiotic environments. While these factors may impact the permissibility of exoplanetary seeding, I argue that they are not as weighty as concerns about interference and suffering, especially when we measure them against the potential value of preserving the story of Earth-originating life in the cosmos.

KEYWORDS: space ethics, directed panspermia, humanity's cosmic footprint, planetary protection, longtermism, intergenerational ethics, environmental ethics, terraforming, exoplanets

TIIVISTELMÄ

Viidestä artikkelista ja johdantoesseestä koostuva väitöskirjani edistää avaruuseettistä keskustelua tutkimalla ulkoavaruuteen liittyviä ympäristöeettisiä kysymyksiä pitkän aikavälin näkökulmasta.

Tutkimus käsittelee erityisesti suunnattua panspermiaa, jolla tarkoitetaan alkeellisten elämänmuotojen tarkoituksellista levittämistä elottomalle taivaankappaleelle pyrkimyksenä muodostaa elonkehä Maan ulkopuolelle. Tällainen elämän kylväminen Maan ulkopuolelle voisi muodostaa ihmiskunnan merkittävimmän biologisen kosmisen jalanjäljen.

Väitöskirjan keskeiset väitteet voidaan tiivistää seuraavasti. Ottaen huomioon epävarmuuden elämän esiintymisestä Maan ulkopuolella sekä tiedon siitä, että elämän edellytykset Maassa tulevat lopulta lakkaamaan, on olemassa painavia syitä elämän levittämiselle keinona turvata Maasta peräisin oleva elämän jatkuvuus. Nämä syyt kumpuavat siitä, että suunnattu panspermia voidaan nähdä tapana luoda hyvää tehokkaasti tai tapana suojella sitä, mikä on arvokasta. Tästä huolimatta suunnatulle panspermialle on merkittäviä vastaväitteitä. Näitä ovat riski vahingon aiheuttamisesta kohdeplaneetan mahdolliselle alkuperäiselle elämälle sekä mahdollisuus levittää kärsimystä, jos ajan myötä kylvetylle planeetalle syntyy tuntoisia olentoja. Näiden vastaväitteiden painoarvo riippuu empiirisistä ja moraalisista epävarmuuksista, jotka ovat vielä ratkaisematta. Näin ollen elämän levittämisen arvo voi osoittautua joko erittäin hyväksi tai huonoksi. Tästä epävarmuudesta johtuen argumentoin, että biologista kontaminaatiota tulisi toistaiseksi välttää.

Tässä tutkimuksessa tarkastellaan myös kahta muuta vasta-argumenttia suunnatulle panspermialle: ”epäluonnollisuus” liittyen elämän levittämiseen Maan ulkopuolelle sekä elottomien ympäristöjen arvo. Vaikka nämä näkökohdat voivat vaikuttaa eksoplaneettojen kylvämisen sallittavuuteen, esitän, että ne ovat lopulta vähemmän painavia kuin yllä esitetyt huolet – erityisesti kun ne asetetaan vastakkain sen mahdollisen arvon kanssa, mikä liittyy Maasta peräisin olevan elämän tarinan jatkamiseen kosmoksessa.

ASIASANAT: avaruusetiikka, suunnattu panspermia, ihmiskunnan kosminen jalanjälki, planeettojen suojelu, pitkän aikavälin etiikka, sukupolvietiikka, ympäristöetiikka, maankaltaistaminen, eksoplaneetat

# Table of Contents

# Acknowledgements

There are many people and institutions that have shaped and enriched my time as a Doctoral Researcher. Here is my warmest thanks to them.

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Expressing my gratitude for those who have helped me along this journey has been a surprisingly daunting task. Who would have known that the acknowledgements end up being one of the hardest parts to write in a thesis? Partly this is because I am afraid that this will be one of the most-read sections in this dissertation. Partly it is because this has been a long journey, and I worry that I will forget something important. If I have, my sincerest apologies. Your help has been valued, I promise.

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Helsinki, October 2025

*Oskari Sivula*

# List of Original Publications

This thesis is based on the following publications, and the text refers to them by their Roman numerals. The original publications have been reprinted with the permission of the copyright holders.

I Sivula, O. (2022). The Cosmic Significance of Directed Panspermia: Should Humanity Spread Life to Other Solar Systems? *Utilitas*, 34(2), 178–194. https://doi.org/10.1017/S095382082100042X

II Sivula, O. (2025). Long-term Future and Non-anthropocentric Value. *Journal of Moral Philosophy*, *1*(aop), 1–25. https://doi.org/10.1163/17455243-20254639

III Sivula, O. (2024). Faking Biosphere. In M. Garasic & M. Di Paola (Eds.), *The Philosophy of Outer Space: Explorations, Controversies, Speculations* (pp. 164–176). Routledge. https://doi.org/10.4324/9781003374381-13

IV Sivula, O. Exoplanetary Seeding and the Value of Abiotic Environments. (A manuscript in the process for M. Puumala, O. Sivula & T. Milligan [Eds.] *Geoethics and Environmental Protection in Space*.)

V Normier, A., Boujibar, A., Boulesteix, D., Sivula, O., Crawford, I. A., Gros, C., ... & Vakoch, D. (2025). A call to address humanity's cosmic footprint. *Nature Astronomy*, *9*(7), 934–935. https://doi.org/10.1038/s41550-025-02606-7

# 1 Introduction

Many space-faring nations are aiming for the Moon again, after more than 50 years of human absence. Soon after such planned Moon landings, we might see the first crewed missions to Mars (Lehto et al., 2025; Levine, 2024). Earth's orbits are at the same time becoming increasingly congested by megaconstellations of commercial satellites, which increases the risk of Kessler Syndrome, or a situation in which orbital collisions generate exponentially increasing debris and can thus render some regions of space unusable for decades, centuries, or even permanently, depending on altitude (Kessler & Cour-Palais, 1978; Kessler et al., 2010). The exploration of potentially habitable worlds is also ramping up in our own Solar System (Coustenis et al., 2025), and space tourism is projected to keep increasing. Some hope to exploit near-earth bodies for valuable resources, while international space law is in turmoil following the Artemis Accords.[1] And outer space is, unfortunately but not surprisingly, becoming more and more a stage for militarisation and geopolitical tensions.[2] Our growing influence in space is not limited only to our system, as some enthusiasts have sent messages to other stars with the hope of attracting attention from

[1] The Artemis Accords are a set of US initiatives laying out non-binding principles for international cooperation in space exploration projects and use of outer space. See https://www.nasa.gov/artemis-accords/.

[2] See, for example, the 9616th United Nations (UN) Security Council meeting on the Resolution on Arms Race in Outer Space in April 2024: https://www.un.org/pga/wp-content/uploads/sites/108/2024/04/240426-PSC-letter-to-PGA-Special-Report-UNSC-9616th-mtg.pdf. In addition, a recent UN policy brief (Policy brief 7: for all humanity – the future of outer space governance: A/77/CRP.1/Add.6 (May 2023)) stated that:

> […] a number of national security strategies, doctrines, concepts, and policies describe outer space as a warfighting or operational domain. These are not just theoretical concepts, they are being backed by the development of military capabilities to deny, disrupt, degrade, or destroy the space systems of adversaries. This can include direct-ascent missiles, manoeuvrable satellites, Earth or space-based laser systems, electromagnetic and cyber capabilities, or even the use of nuclear weapons.

possible extraterrestrial intelligence (ETI). Moreover, interstellar probes are being designed for scientific purposes (Lantin et al., 2022), which in the future could also help seed exoplanets with rudimentary lifeforms.

All of this space activity raises profound ethical questions, and the burgeoning field of *space ethics* aims to address them. The so-called New Space phenomenon is accelerating our space activities and as such increases the *cosmic footprint* of humanity beyond Earth (article V). This study is a contribution to this unfolding dynamic and the growing literature on space ethics by investigating environmental ethical questions concerning outer space from a long-term perspective. More specifically, this thesis investigates the ethics of disseminating simple lifeforms beyond Earth, by means of *directed panspermia*.

This dissertation consists of five articles to examine questions about the spread of life to space, preceded by an introduction and summary to contextualise all five. The structure of this introductory essay is as follows. In Section 2, I describe the background of this dissertation, including 1) the concept of humanity's cosmic footprint as a conceptual lens for viewing the thesis, 2) how this study connects to planetary protection, 3) the history of directed panspermia and practical proposals for seeding life on new worlds, 4) the field of space ethics, to which the ethics of directed panspermia belongs to in particular, 5) longtermism, an ethical theory examined in this study, and finally 6) the discussions in environmental ethics that pertain to the thesis. I also review my strategy for taking non-anthropocentric values into consideration. The strategy is modest but epistemically robust, as it avoids overstating confidence in any one theory of value. After the background, Section 3 elaborates on my aims and lays out the central claims of the dissertation. Section 4 takes on the approach and methods. I pay special attention to how the thesis is carried out in the spirit of the wide reflective equilibrium method. In the concluding section, I summarise the results.

# 2 Background

This study stems from my interest in three fields: space ethics, environmental ethics, and intergenerational ethics. I wanted to bring these three branches of moral philosophy into a dialogue and explore the questions that emerge at their intersection. My work began in early 2020, when I started to scan the literature for environmental ethical question concerning outer space. In the process, the question of directed panspermia caught my attention. Directed panspermia is the idea of intentionally seeding habitable celestial bodies with life to create new biospheres. The idea is often understood as an off-Earth process, although it is also an unlikely explanation for the origins of life on Earth. Directed panspermia is frequently used to refer to the idea of seeding exoplanets, or planets outside the Solar System, and so can also be called *exoplanetary seeding* (see articles II and IV). We shall deal with the idea more in Section 2.2.

The reason that directed panspermia caught my attention is that it was an under-studied topic in the space ethical literature. More importantly, it raises many questions fundamental to environmental philosophy in a novel, interesting setting. It is also a good example of an issue that benefits from adopting a very long-term perspective—a perspective known to cause problems for ethical theorising.

At the same time, an ethical view called *longtermism* was gaining visibility in academic philosophy. Toby Ord (2020) characterises longtermism as the view that we should pay special attention to the long-term consequences of our actions. William MacAskill (2022) says that longtermism boils down to the idea that improving the long-term future is a key moral priority for our time.[3] In this regard, it falls under the branch of intergenerational ethics, as it considers the obligations we have toward future generations. While longtermism offers an interesting philosophical framework for examining the ethics of exoplanetary seeding, the case of

[3] Longtermism has been defined in many ways. Indeed, Stephen Gardiner (2025) has pointed out that the term longtermism seems to lack a stable meaning and this is a source of confusion.

directed panspermia also reveals new aspects of longtermism and advances the debates about it. Therefore, this thesis also contributes to the discussion surrounding longtermism, as I shall do later in section 2.5.

Before treating directed panspermia in detail, I must first introduce the concept of humanity's cosmic footprint to situate my study as an inquiry into the biological cosmic footprint of humanity's space endeavours. We shall then be able to examine how these footprints and directed panspermia link to issues of planetary protection.

## 2.1 Humanity's Cosmic Footprint

Humanity's cosmic footprint is a new conceptual lens through which we can see many of the issues in this dissertation.

During my doctoral research I have been part of an international research group, established by Adrien Normier, for investigating ethical questions about space from multidisciplinary perspectives. In January 2024, the International Space Science Institute (ISSI) in Bern, Switzerland, hosted a three-day workshop, and there our team convened to explore issues in space ethics. [4] From that work the concept of a cosmic footprint began to crystallise. The concept aims to capture the myriad impacts human space activities have beyond Earth. As discussed throughout this dissertation, humanity's increasing capability for causing substantial and, in some cases, irreversible impacts in outer space, validates the need for this organising principle.

Based on our work at ISSI, we drafted an open letter to highlight ethical concerns surrounding space activities, to promote ways of managing humanity's cosmic footprint and to encourage establishing an international cosmic footprint registry. As we envision in the publication, the registry would compile information about the impacts of human space activities. It would identify, merge, collect, and model data to form a comprehensive scientific account of our cosmic footprint that could function as a shared foundation for global discussion. The open letter was published in *Nature Astronomy* and, as of 10 August 2025, more than 100 scientists and experts have signed it, including astrophysicists, astrobiologists, ethicists, a European Space Agency (ESA) astronaut, a former National Aeronautics and Space Administration (NASA) chief historian and representatives from commercial space industries (see article V).

[4] For a report on the workshop, see https://forum.issibern.ch/cosmicfootprint/report/.

Within our research group, we have provisionally outlined a typology for humanity's cosmic footprint, based on the kinds of impacts our activities could have in space. We have identified at least three broad and often overlapping categories of cosmic footprint, each of which raises distinctive ethical questions. The three categories are (a) physical, (b) biological and (c) informational.

The *physical* cosmic footprint refers to anthropogenic physical impacts and to traces of activity left in space. This category would encompass physical objects sent into space, as well as physical changes and vestiges left by human activities in space environments. A clear example of this is space debris on Earth's orbits. Landers, rovers, and various scientific apparatus, along with human-created impact craters on celestial bodies such as the Moon and Mars, are also part of the physical footprint. Asteroid deflection experiments, prospective extraterrestrial mining operations, and future settlements beyond Earth further illustrate this expanding footprint.

Besides sending physical objects and leaving physical traces and alterations to space environments, we may also send life into space, forming humanity's *biological* cosmic footprint. Humans have visited the Moon, for example, and tiny, resilient organisms called tardigrades ('water bears') were also sent in 2019. The water bears were sent with no notice to the public and so caused some controversy. They crashed on the Moon so violently that the organisms probably did not survive the impact (O'Callaghan, 2021). Apart from intentionally sending life into space, microbes can also inadvertently hitchhike on equipment sent to other celestial bodies. Owing to this biocontamination risk, the Committee on Space Research (COSPAR) has developed planetary protection guidelines, which I shall explain in section 2.2. This dissertation is ultimately about the ethics of our biological footprint with the specific ambition to look at our potential biological footprint beyond the Solar System.

Third and finally we have humanity's *informational* cosmic footprint. Travelling aboard the interstellar Voyager probe is the 'Golden Record', with images and sounds representing humans and Earth-life. Should anyone ever find it, they would learn who we are and where we came from, even if at that point we no longer exist (Heyd, 2024). More recently, the crashed lunar lander had a library with more than 30 million pages of information.[5] Unlike the unfortunate tardigrades, the library is thought to have survived the impact. In 2024, another 'lunar library' was sent to the

[5] See https://www.archmission.org/spaceil.

Moon, this time successfully. These time capsules include astonishing amounts of information, such as books, music, films, images, art, an archive of world languages and the whole English Wikipedia etched onto thin sheets of nickel in highly durable storage that could last for aeons (Jones, 2024). In addition, messages have been sent towards the stars, with the hope of attracting notice from extraterrestrial civilisations. In 2018, for example, a powerful radio signal was transmitted from Tromsø, Norway, towards a potentially habitable exoplanet, Luyten b, 12.4 light-years away. The goal is to make contact with ETI.[6]

There could be other ways of categorising humanity's cosmic footprints, of course. One could focus on other issues, such as the impact's temporal or spatial influence or its mechanisms. What is useful about these categories is that they all raise different ethical questions. Let me illustrate.

The physical cosmic footprint raises questions about the value of space environments and the possible need to protect them. The biological footprint goes further by asking us to consider the organisms in space and the future development of any biological components. The informational footprint, in turn, raises more Earth-bound questions, such as what is the rationale for documenting our existence and leaving information traces of us beyond Earth, or whether it is acceptable for a small group of METI enthusiasts to impose risks on the rest of us even if the risks are likely miniscule—who speaks for humanity in these matters, and how should we decide on such matters that affects collectively the whole Earth? For future research, an important aspect of understanding our cosmic footprint is to compare how it stands out from natural elements or dynamics. For example, how our radio emissions compare against the background radio waves caused by the Sun or how anthropogenic microbial transfer in the Solar System compares to natural transfer via meteorites.

Because it is an ongoing work with the research group to further develop the concept of humanity's cosmic footprint and its typology, I will not develop these strands of thought further here. I close only by noting that our cosmic footprints do raise important ethical questions, and these will demand careful consideration as human activities in space increase (V). This dissertation, therefore, is an effort to increase our understanding

[6] See https://www.sonarcalling.com/en/. Messaging Extraterrestrial Intelligence (METI) is the controversial cousin of Search for Extraterrestrial Intelligence (SETI), which aims to find evidence of intelligence beyond Earth by passive observation. Because METI actively aims to make contact with ETI, it is sometimes called *active SETI*.

of these and other questions related to humanity's biological cosmic footprint.

The most significant effort to govern our biological cosmic footprint is planetary protection. I turn to this issue next.

## 2.2 Planetary Protection

The term *planetary protection* refers to efforts to avoid harmful biological contamination of celestial bodies or of Earth, in compliance with the Outer Space Treaty (OST) of 1967 (Coustenis et al., 2025).[7] Article IX of the Treaty states that:

> States Parties to the Treaty shall pursue studies of outer space, including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose.

Planetary protection thus consists of safeguards against two problems: *forward contamination* and *backward contamination*. Forward contamination refers to Earth-based microbes spreading to extraterrestrial environments, whereas backward contamination is the potential contamination of Earth by extraterrestrial matter (Persson et al., 2018; Coustenis et al., 2025). To manage the risk of both and to guide compliance with OST, COSPAR has since 1964 maintained a policy on planetary protection that involves protocols for minimising the risk of harmful contamination. The latest version of the COSPAR policy appeared in 2024 (see Ehrenfreund et al., 2024). COSPAR's planetary protection guidelines enjoy widespread international support and thus have considerable authority in the global scientific community despite not being legally binding under international law (Coustenis et al., 2025).

This shows that the issue of sending microbes to other celestial bodies is in no way new. However, the discussions have typically had limited spatial scope. In addition, debate tends to resolve around the notion of planetary protection that is primarily focused on protecting scientific

[7] OST is the primary international treaty governing outer space activities. It forms the cornerstone for international space law. The treaty's full name is *The Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies.*

studies. COSPAR concerns itself mainly with avoiding false positives and with the risk of destroying valuable sites or entities of study (Cockell, 2005; Persson et al., 2018; Puumala et al., 2025). But there might also be other reasons to avoid spreading life beyond Earth; the ethics of directed panspermia can uncover fresh insights about these issues.

While OST does not define a geographical, or rather spatial limit, thus tacitly implying that its principles extend as far as space exploration goes, almost no one uses Article IX of OST to object to exoplanetary seeding. This is probably because, as just noted, planetary protection measures focus mainly on protecting astrobiological research—and because the distances to exoplanets are immense, our practical ability to study them is poor, compared with what we can do with celestial bodies in our own Solar System.[8]

In addition to the differences in our ability to engage with far-away celestial bodies compared to the ones close to us, there are other discrepancies that may be relevant. For instance, take Mars, the most Earth-like planet in our Solar System. First, Earth microbes may already have spread to Mars at various times in the past: natural transfer of microbes could occur from Earth to Mars (or vice versa) via meteorites ejected into space when a sufficiently strong impact strikes the planet (see, e.g., Gladman, 1996; Mileikowsky et al., 2000). Despite planetary protection measures, some microorganisms might also have hitchhiked to Mars on landers, rovers, and other science equipment, as it is impossible to keep them perfectly clean (Debus, 2005). Second, a complex biosphere is much more likely to emerge on a suitable exoplanet compared with the likelihood on Mars, owing to the Red Planet's harsh environment.[9] Third, Mars's habitability is tied to our Sun, meaning that some exoplanets orbiting younger or more long-lived stars could host life for considerably longer than either Earth or Mars. In light of these differences, we must discuss the ethics of planetary seeding beyond conventional planetary protection discourse.

[8] See discussion in article IV of this dissertation. Ideally, a planetary protection policy would operationalise a wider set of ethical concerns, as there are many ethical questions beyond those touching on science (such as those I deal with in this study).

[9] For a compact description of the harsh conditions on Mars, see the first paragraph of article III.

## 2.3 Directed Panspermia

Directed panspermia is the deliberate dissemination of rudimentary lifeforms to celestial bodies with the intention of creating off-Earth biospheres (articles I, II and IV). I here present the history of this idea followed by an outline of current practical proposals for how exoplanets could be seeded.

### 2.3.1 History of Directed Panspermia

The origin of life on Earth is among science's biggest questions. The prevailing view is that life arose on Earth from non-living materials. This *abiogenesis* theory, however, faces some challenges, given that the spontaneous generation of life has never been observed to occur on Earth, despite efforts to reproduce the transition from non-living materials to living organisms. An alternative hypothesis says that if we cannot observe life emerging spontaneously from abiotic matter on Earth, then perhaps it never happened. It could be that life migrated to Earth from outer space. This theory is known as *panspermia*.

The term 'panspermia' has roots in the work of Greek philosopher Anaxagoras (500–428 BCE), who believed that life originated when seeds fell from heaven to Earth (Mitton, 2022). It was a long time before panspermia entered scientific discussion as a legitimate explanation for life's origins, however. The first proposal came in 1908 from Swedish physicist and chemist Svante Arrhenius, who speculated that microscopic lifeforms could have drifted to Earth from space, carried by radiation pressure from a distant star. This hypothesis is called *radiopanspermia*, for the method of transportation. Another variation, now considered more plausible, suggests that life may have arrived on Earth via a meteorite or comet in a process known as *lithopanspermia*.

These theories, which rely on accidental transport, faced criticism initially because space is a hostile and dangerous environment for life (Crick & Orgel, 1973; Ginsburg & Lingam, 2021; Mitton, 2022). At the very least, long journeys through space would expose any lifeforms to extreme levels of radiation, which were thought to be fatal. But the possibility of a natural transfer of life between planets has since gained more scientific credibility. It no longer seems so implausible because experimental results show some microbes to be surprisingly resilient against the harsh conditions of space, even having long survival times, as long as they are protected by a transport vehicle such as a meteorite or comet (e.g., Horneck et al., 2008; Valtonen et al., 2009; Changela et al., 2021). We now also know

that when a large asteroid or comet strikes a planet, the impact can eject surface material so forcefully that rocks reach space (e.g., Gladman, 1996; Mileikowsky et al., 2000). Some of these fragments could land on other planets. Such material exchange has occurred between Earth and Mars. These ejected meteorites could serve as space vehicles for tiny organisms capable of surviving extreme conditions, known as *extremophiles* (Weiss et al., 2000), before crossing paths with another celestial body. They might even carry viable microbes interstellar distances (Ginsburg et al. 2018).

This leads us to a situation where either life emerged spontaneously on Earth under just the right conditions, through complex chemical and physical processes, or it might have naturally arrived from another planet. However, there is also a third possibility. This speculative alternative came from a seminal 1973 paper entitled 'Directed Panspermia' by physicist and molecular biologist Francis Crick with chemist Leslie Orgel. The authors investigated the idea that primitive life was deliberately seeded on Earth by some technologically advanced extraterrestrial civilisation. According to Idan Ginsburg and Manasvi Lingam (2021), even though Crick and Orgel coined the term, the idea of intelligent actors spreading seeds of life through space had already appeared in work by John Haldane (1954) and Iosif Shklovsky and Carl Sagan (1966). Ginsburg and Lingam also point out that the idea appears in the science fiction novel *Last and First Men* (1930), by philosopher and author Olaf Stapledon.[10]

To argue for their directed panspermia hypothesis, Crick and Orgel (1973) note that the first planets in our galaxy that could have harboured life formed long before our own star system. These early planets and their stars formed so long ago that, in principle at least, technologically advanced civilisations might have already existed around the time Earth came to be. The authors considered the technological feasibility of directed panspermia and argued that, given humanity's then-current level of technological advancement, we might soon have the tools necessary to deliberately spread life to exoplanets. Therefore, they conclude, directed panspermia is a viable hypothesis for the origins of terrestrial life. As they sum up their argument from cosmic reversibility: "if we are capable of infecting an as yet lifeless extrasolar planet, then, given that the time was available, another technological society might well have infected our planet when it was still lifeless" (ibid., 323). Even though directed panspermia was initially proposed as an alternative for abiogenesis and

[10] Astrophysicist Thomas Gold (1960) also said, perhaps as a clever jest, that life on Earth might have evolved from garbage left behind by extraterrestrial visitors.

natural panspermia, it has since attracted attention as something that humans could actually try (see, e.g., Mautner & Matloff, 1979; Mautner, 1997; Tepfer, 2008; Gros, 2016; 2019; McKay et al., 2022). We turn to this issue next, with recent practical proposals for directed panspermia.

### 2.3.2 Practical Proposals for Directed panspermia

In 1995 researchers discovered the first planet orbiting a star similar to our Sun (Mayor & Queloz, 1995).[11] Scientists have since confirmed more than 5,800 exoplanets[12] and new discoveries keep on coming. Space and biotechnology have at the same time made significant advances, and it is now possible to have serious discussions about exoplanetary seeding. In addition, there is no sign anywhere of extraterrestrial life, either in our Solar System or beyond it. It may be, then, that while many habitable planets exist, life is rare.[13] The possibilities make directed panspermia all the more intriguing.

By the end of the 1970s, Michael Mautner and Gregory Matloff (1979) had already suggested using solar radiation pressure harnessed by solar sails to propel smaller payloads towards nearby star systems. On arrival, these spacecrafts would release tiny 'pansperm' capsules, each holding microorganisms, to seed life on a target planet intersecting with the cloud or ring of inoculated capsules.

More recently, Claudius Gros (2016) has proposed a *Genesis project*, which would consist of three phases: searching for habitable planets, sending interstellar robotic probes to investigate, and seeding candidate planets with lifeforms. Gros has argued that lightweight interstellar probes with light sails could be accelerated by laser arrays in the direction of planetary candidates that are habitable but otherwise appear lifeless. The requisite laser-powered directed energy system to accelerate small spacecrafts are being designed as part of the NASA Starlight programme (Lantin et al., 2022). The programme's aim is to achieve significantly higher speeds for spacecrafts than those achievable by traditional propulsion

[11] The very first exoplanet discovery was made slightly earlier, in 1992, when not one but two exoplanets were discovered orbiting a pulsar (a type of neutron star) (Wolszczan & Frail, 1992).

[12] See https://exoplanetarchive.ipac.caltech.edu/docs/counts_detail.html for precise and updated numbers.

[13] For a helpful philosophical discussion about optimism in the search for extraterrestrial life, see Cowie (2025). Christopher Cowie argues that it is not obvious that we should be confident about extraterrestrial life being common despite recent advances in scientific knowledge.

technology. Such a venture would also benefit Solar System exploration (Popkin, 2017; see also Parkin, 2018). Simply put, the idea is to use conventional propulsion to send sail-equipped nanocrafts into Earth's orbit. The laser array would then fire continuously at the sail and accelerate the craft towards its destination. It is worth noting that interstellar space exploration received a boost in 2016 when the Breakthrough Starshot was announced. Breakthrough Starshot is a proof-of-concept project for ultra-fast interstellar nanocrafts. The effort was backed with USD 100 million by Breakthrough Initiatives (Popkin, 2017).

To seed exoplanets, such tiny spacecrafts would carry well-protected payloads of microorganisms, including bacteria and unicellular eukaryotes. Stephen Lantin and colleagues (2022, p. 264) have argued that, for interstellar flights, we should select species with "low metabolic rate per unit mass, cryptobiotic capability, and high radiation tolerance" to ensure both survivability and practicality. The payload could be arranged to fulfil the Genesis mission's goal, which is to kick-start a self-developing extrasolar biosphere (Gros, 2016).[14] Perhaps future advances in remote atmospheric studies will enable customisation of specific microbes for particular planets, which would help to ensure that a biological payload had essential genetic tools needed for life to adapt and flourish in the new surroundings (Sleator & Smith, 2017).[15] Deceleration to ensure smooth arrival to the target system could be done by magnetic sails, although this problem is probably much more difficult to solve than accelerating in the first place (Gros, 2019). The seeding could happen from orbit by ejecting capsules carrying the organic material. Asher Soryl and Anders Sandberg (2025, p. 398) have argued that "a simple opening mechanism such as thermal expansion could release [the capsules] randomly in a habitable zone without requiring the use of electronic components."

Gros (2016) has suggested transiently habitable planets as potential targets. A transiently habitable planet is one that passes through a window of conditions suitable for life, perhaps owing to changes in its star's luminosity, orbital dynamics, or atmospheric composition, but only for a limited time. Such planets could be prime candidates for directed

[14] Plant seeds have also been suggested as potential cargo for transferring life through space. See Tepfer and Leach (2006) and Tepfer (2008).

[15] Some have even suggested that in the future microbes could be constructed on the probe, with a robotically operated gene lab, after planetary contact. This would help to create the right mix of microbes in situ based on the target planet's environmental conditions (Gros, 2016; Sleator & Smith, 2017).

panspermia, as their environments may be rich enough to support life but too short-lived for complex organisms to arise naturally. There may be many such places, but because their habitability is transient, life may not have the time to evolve on its own: after all, it took almost 3 billion years for multicellular life to evolve on Earth after the first known single-celled organisms appeared. Other candidates for seeding, according to Gros (2019), are habitable but sterile oxygen planets orbiting M-dwarf stars. Primordial oxygen atmospheres on these planets may prevent abiogenesis from occurring at the outset even though the planet would otherwise be habitable. From an ethical perspective, targets like those might be ideal because they decrease the risk of interfering with potential indigenous life at the seeded exoplanet.[16]

As another approach to seeding, Christopher McKay and colleagues (2022) have suggested the use of interstellar comets as low-cost vehicles for directed panspermia. The proposal is to identify transiting interstellar comets, intercept them while they traverse our Solar System and then inoculate the cometary nucleus with a biological payload that could survive the journey. To help reach a target and lessen travel time, an orbital correction might be necessary. Regarding the mechanisms for how the microbial life on the comet would reach its target, the authors argue that:

> If we consider inoculum injected to depth within a comet, then as the comet moves through the target star system and loses dust this inoculum will be disseminated as well. Depending on the perihelion distance and the resulting spread of the dust, some fraction of this emission could settle into planetary atmospheres, eventually reaching the surface. (ibid., p. 1446.)

While it is true that much of this discussion is speculative and still beyond our technological capabilities, disseminating life to exoplanets seems at least to be a foreseeable possibility. Many technical challenges remain, however. These need to be overcome before seeding exoplanets is feasible with any significant probability of success.[17] One must remember that exoplanets, even the closer ones, are *very* far away. Nevertheless, ongoing progress in science and technology suggests that it could become a reality

[16] Michael Mautner (2009) has proposed that by seeding young star systems, we can reduce the probability of interfering with native lifeforms, since in such systems life—especially advanced life—would be unlikely to have evolved.

[17] Eventually, seeding could be attempted multiple times; this would increase the chances of success.

during this or the next century. Futurist Roy Amara has famously said: "We tend to overestimate the effect of a technology in the short run and underestimate the effect in the long run" (Amara, cited in Ratcliffe 2016). The same likely applies to space technology and to humanity's ability to have far-reaching impacts beyond Earth, namely the cosmic footprint that we may have. It is therefore important to consider the ethics of directed panspermia sooner rather than later.

Indeed, if ethical inquiry suggests that spreading life to the stars is unethical, there would be good reasons to ban the development of technology needed for directed panspermia. Afterall, it is not wise to use resources for developing ethically dubious technologies. Unfortunately, though, it may simply turn out that no 'special' technology is needed for planetary seeding, and so the ability to seed exoplanets may come about as a by-product of more general developments in space technology.

Certainly, advances in space technology raise new ethical issues. These belong to the field of space ethics, which we consider next.

## 2.4 Space Ethics

The ethics of spreading life beyond Earth belongs to the field of space ethics. As the field is still small, I wish to characterise it here and give a short historical account of its development before arguing for the relevance of space ethics.

### 2.4.1 Characterising Space Ethics

Space ethics is the study of ethical and societal question related to space, especially regarding human activity in space both now and in the future (cf. Milligan & Schwartz, 2023).[18] As a field of academic philosophy, it is most clearly a sub-branch of applied ethics. It is a relatively new but a growing field of inquiry. Characteristic is the field's interdisciplinarity, as those working in it come from many backgrounds, including astrobiology and other space sciences, law, sociology, political sciences, anthropology, future studies, and sustainability studies. However, "the majority of scholars who self-identify as space ethicists are professional philosophers" (ibid., p. 108).

[18] There may be space ethical questions that do not cover human activity *in* space *per se*. For example, the ethics of meteorite hunting might belong to space ethics, even though it deals with practices on Earth.

Although the term *astroethics* is used as a synonym for space ethics (see, e.g., Arnould, 2018; Lindquist, 2022; 2024), *space ethics* is more common. Space ethics is sometimes confused with *astrobioethics* but even though the latter term is related to the former, *astrobioethics* has narrower scope and is better understood as a sub-field of space ethics. According to Octavio A. Chon-Torres (2017, p. 51) astrobioethics is the study of "the ethical implications of astrobiological research", and Erik Persson (2023, p. 237) defines it "the study of ethical questions in connection with astrobiology."

To see the difference between space ethics and astrobioethics, consider the cultural significance of space. Discussions around the idea of lunar heritage, which led to sites on the Moon being added to the World Monument Funds' list of threatened cultural sites in 2025,[19] can be argued as belonging to the discourse of space ethics since it included ethical arguments. But these arguments do not belong to the subdiscipline of astrobioethics, as defined above, because it falls outside the scope of astrobiology, which is the "study of the origin, evolution, and distribution of life in the universe" (Irvine, 2023, p. 241). For these differences, and for the fact that 'space ethics' is the more common usage, I adopt that term in this work.

### 2.4.2 A Short History of Space Ethics

Space has long inspired philosophers. Thales of Miletus was famous for predicting a solar eclipse in 585 BCE (Curd, 2023). Over two millennia later, Blaise Pascal gave voice to the haunting feeling of cosmic insignificance one gets when considering the vastness of the universe compared with our own glimmer of existence:

> I see those frightful spaces of the universe which surround me, and I find myself tied to one corner of this vast expanse, without knowing why I am put in this place rather than in another, nor why the short time which is given me to live is assigned to me at this point rather than at another of the whole eternity which was before me or which shall come after me. […] When I consider the short duration of my life, swallowed up in the eternity before and after, the little space which I fill, and even can see, engulfed in the infinite immensity of spaces of which I am ignorant, and which know me not, I am frightened […].

[19] See https://www.wmf.org/monuments/moon.

> The eternal silence of these infinite spaces frightens me (Pascal 1670/2016, fragments 194, 205 and 206).

Immanuel Kant (1787/2009, p. 863) was convinced that at least some of the planetary bodies known in his time were inhabited by ETI. He was so certain about extraterrestrial habitats in our Solar System that, in the *Critique of Pure Reason*, he said that he would wager many good things in life on the matter.

These early writings, though, had little ethical content. That is unsurprising given that no one had gone to space. Among the first papers to be properly labelled as belonging to space ethics is Hannah Arendt's 1963 essay "Man's Conquest of Space". Here Arendt examines the new scientific accomplishment of spaceflight and argues that this modern technological advancement runs the risk of alienating humans from Earth and nature. According to Arendt, modern science riddles life with artificiality; everything tends towards being human made or being such that humans could control it. Space exploration escalates the process, as Arendt goes on to argue (ibid., pp. 537–538):

> The astronaut, shot into outer space and imprisoned in his instrument-ridden capsule where each actual physical encounter with his surroundings would spell immediate death, might well be taken as the symbolic incarnation of […] the man who will be the less likely ever to meet anything but himself and man-made things the more ardently he wishes to eliminate all anthropocentric considerations from his encounter with the non-human world around him.

In this sense, human conquest of space quite surprisingly diminishes human stature contrary to the very physical ascent of humans towards the heavens, according to Arendt.

It took an additional two decades from Arendt's paper for more substantial academic discussion about space ethics to arise. This happened in 1980's due to advances in space science and also because the idea of terraforming started to receive more attention. Terraforming is the hypothetical process of engineering environmental conditions on a celestial body for them to conform better to what we know on Earth. The process would eventually entail transportation of Earthly organisms to the terraformed environment for them to live there and continue the terraforming.

Terraforming is closely connected to directed panspermia, as discussed in article IV. The two processes differ in that when a celestial body is terraformed, its environment is engineered to make it more hospitable to *human* life. With Mars, for instance, this would mean increasing the temperature and atmospheric pressure by means of, say, solar mirrors or engineered aerosols (DeBenedictis et al., 2025). Directed panspermia, in contrast, just seeds rudimentary forms of life on planets that are already habitable. While both processes are similar in terms of involving the transport of living organisms from Earth to other celestial bodies, which would alter conditions at the destination, directed panspermia is less invasive than terraforming (for more on terraforming see article III).

In 1991, the idea of terraforming Mars received considerable press attention when *Nature* published a cover article on it (McKay et al., 1991). At the time, the prospect of terraforming the Red Planet seemed more feasible than it does now.[20] Despite the current implausibility, the research raised the important question of, if we could render Mars habitable, is it also something that we are *allowed* to do or even something that we *should* do?

Issues around terraforming are particularly significant for environmental philosophy. While many of the associated ethical questions mirror familiar environmental ethical debates encountered on Earth, they take on heightened intensity when considering the massive scale of altering a whole planet and relocating life between worlds (Forget et al., 2025). It is no wonder, then, that the moral permissibility of terraforming is among the most discussed topics in space ethics (see, e.g., Haynes, 1990; McKay, 1990; Lee, 1994; Sparrow, 1999; Schwartz, 2013; Milligan, 2015; McMahon, 2016; article III).[21]

Space ethics and environmental ethics have always been closely linked. The first edited volume on space ethics, *Beyond Spaceship Earth: Environmental Ethics and the Solar System* (1986), came from the Sierra Club, a grassroots environmental organisation, and was edited by environmental philosopher Eugene Hargrove. Soon after this groundbreaking volume, the philosophy journal *The Monist* published a special issue on philosophical

[20] For a critical overview of terraforming Mars, see Forget et al. (2025). For a more optimistic review, see DeBenedictis et al. (2025).

[21] See Rolston III (1988) as well as Marshall (1993). While Rolston III and Marshall do not specifically address the ethics of terraforming, they argue for the protection of outer space environments based on the value of inanimate environments beyond Earth.

problems of space exploration. These points mark the formation of space ethics as a distinct philosophical subdiscipline.

However, for some time, natural scientists and others from the space community where more active in discussions about space ethics.[22] It was only sometime around 2010 or so that philosophers began to engage with the issue more intensely (Milligan & Schwartz, 2023). This is because private actors such as Space X and Blue Origin started to make splashes in the space ecosystem and draw attention to space activities. This development made many space ethical issues more acute. You could call this the second wave of space ethics that gave us books such as Jacques Arnould's *La Seconde Chance d'Icare* (2001), expanded and translated as *Icarus' Second Chance: The Basis and Perspectives of Space Ethics* (2011); Tony Milligan's *Nobody Owns the Moon: The Ethics of Space Exploitation* (2015); JS Johnson-Schwartz's *The Value of Science in Space Exploration* (2020a); edited volumes such as Schwartz's and Milligan's *The Ethics of Space Exploration* (2016); Charles Cockell's *Human Governance Beyond Earth: Implications for Freedom* (2015a), *The Meaning of Liberty Beyond Earth* (2015b) and *Dissent, Revolution and Liberty Beyond Earth* (2016); Jai Galliott's *Commercial Space Exploration: Ethics, Policy and Governance* (2016); Konrad Szocik's *The Human Factor in a Mission to Mars: An Interdisciplinary Approach* (2019); and Kelly Smith's and Carlos Mariscal's *Social and Conceptual Issues in Astrobiology* (2020) (cf. Milligan & Schwartz 2024, p. 111). Also, the Society for Social and Conceptual Issues in Astrobiology (SSoCIA) held its first conference in 2016 and has since then been meeting biannually. SSoCIA is one of the first organisations to focus on philosophical issues in space exploration.

Now, in 2025, the field of space ethics remains small. But it is vibrant and growing. New articles, books, and edited volumes appear all the time. Arguably, they belong to a third wave that will permanently establish space ethics as a serious branch of philosophy.

A substantial proportion of the work that can be labelled as space ethics have been works of environmental ethics. This is not surprising, given that

[22] The United Nations Educational, Scientific and Cultural Organization (UNESCO) interest in space ethics led to the 1998 formation of an interdisciplinary working group, a joint effort between ESA and the UNESCO World Commission on the Ethics of Scientific Knowledge and Technology (COMEST). The group was tasked with examining the ethical implications of space activities. Its output was *The Ethics of Space Policy* (2000) report, led by Alan Pompidou. And for those who are interested, see also Arnould (2004), for an account of how ethics of space exploration developed within the French Space Agency CNES.

environmentalism had early connections to space exploration. The very first colour photographs of Earth taken from space, notably the Earthrise photo, helped the environmental movement in the 1960's to gain momentum as this imagery created an awareness of our planet as something extremely valuable and one of a kind, even fragile (Gerretsen, 2024). More theoretically, space ethics is interesting for environmental ethics because, as Michael Lindquist (MS) claims,

> Outer space environments present peculiar challenges for environmental ethics. Within Earth-bound environmental ethics, theorists often focus on life and the regions life inhabits. Outer space, however, presents us with vast abiotic environments – entire planets devoid of life. This poses interesting problems for environmental ethics, as the appeal to life no longer works if one believes that these places are worthy of protection as well. As animal ethics challenges the norms of traditional anthropocentric ethics, and environmental ethics challenges the norms of animal ethics, emerging astroethics challenges the norms of environmental ethics.

Article IV discusses the challenge of abiotic environments to ethical theorising and examines whether the value of abiotic environments gives us reasons against exoplanetary seeding. More broadly, thinking about alien environments or lifeforms in space can help deepen our understanding of the variety and extent of value in nature both within and beyond Earth.

The topic of this study, directed panspermia, falls into what may be termed *environmental space ethics* and likewise does the question of terraforming. In addition, there has been extensive discussion regarding environmental protection in space on a more local scale. For instance, much thinking has addressed how we ought to conceive the value of microbial life (which is the form of extraterrestrial life we are most likely to encounter), and the normative implication of this value in space (e.g., Cockell, 2005; Milligan, 2015; Persson, 2012; Smith, 2016). Environmental protection in space also connects to the issues of planetary protection (see Section 2.2), as well as to the value of abiotic environments and that value's consequences for off-Earth activities such as research, mining, settlements, terraforming, or planetary seeding (IV). Planetary 'parks' (e.g., Capper, 2022; Cockell & Horneck, 2004; Elvis & Milligan, 2019) or frameworks of *exogeoconservation* (e.g., Fletcher et al. 2024; Matthews & McMahon, 2018) have been suggested as ways to protect valuable sites in space. In addition,

some advocate for protecting cultural heritage sites in space (e.g., Holcomb et al., 2024; Walsh, 2012).

Some environmental issues arise closer to Earth, however. Examples include the problem of orbital debris and the degradation of dark skies from satellites (which hamper ground-based astronomy; see Lawrence et al., 2022). The environmental impact of space activities and associated concerns of environmental justice offer other examples (see, e.g., Klinger, 2021; Matravers et al., 2024), as do the increase in atmospheric pollution from the de-orbiting of satellites (Flamm et al., 2024) or the global warming impacts of human space travel (Carbajales-Dale & Murphy, 2023).

Apart from strictly environmental ethical concerns, a critical examination of the values, motivations, and justifications underpinning space exploration occupies a prominent place in the literature of space ethics (see, e.g., Billings, 2006; Cockell, 2007b; Deudney, 2020; Milligan, 2015; Schwartz, 2014; 2017a; 2017b; Tutton, 2021). In particular, serious debate has centred on the issue of space settlements, or the colonisation of space. A central question within these debates has been: why settle space? What rationales could support such a settlement, and could those rationales hold up to scrutiny against the realities of space travel (see, e.g., Billings, 2017; Puumala et al., 2023; Schwartz et al., 2021; Smith et al., 2019)?

Mikko Puumala, Kirsi Lehto, and I have argued that it is useful to distinguish between *pre-settlement*, *in-settlement*, and *post-settlement* discussions (Puumala et al., 2023). Questions about the pre-settlement stage include those just mentioned, such as the justification and motivation for establishing habitats beyond Earth. In-settlement discussion deals with issues expected to arise within settlements. These might include problems of civil liberties among early settlers (Persson, 2015), political systems and freedom in space (e.g., Cockell, 2015a; 2015b; 2023; Wójtowicz & Szocik, 2021) or bioethical concerns about reproduction in future settlements (e.g., Balisteri & Umbrello, 2022; Kendal, 2024; Szocik et al., 2018).[23] Post-settlement discussions, in turn, examine concerns emerging after settlements become well-established, including self-sufficient societies beyond Earth. Two examples are the geopolitics of Earth–Mars relations (Deudney, 2020) and the sovereignty of Mars (Haqq-Misra, 2023).

Other important issues within space ethics include questions of ownership and resource governance in space (see, e.g., Elvis et al., 2016; 2021; Elvis & Milligan, 2019; Grayling, 2024; Milligan, 2011; Schwartz, 2016) and bioethical considerations for astronauts, such as human enhancement

[23] For book-length treatments predominantly concerned with in-settlement issues, see Nesvold (2024) and Verseux et al. (2024).

(see, e.g., Gibson, 2006; Huttunen & Sivula, 2023; Szocik, 2020; Szocik & Wójtowicz, 2019). Research-ethical questions concerning space exploration are also notable (e.g., Chon-Torres 2018; Haramia et al., 2025; Marino et al., 2023; Rahimzadeh et al., 2023). Likewise, social justice issues, such as diversity and inclusivity in space-related activities or multicultural visions of what space ought to be like in the future, have recently become more prominent (see, e.g., Aganaba et al., 2025; Kendal, 2023; Milligan, 2023; Neilson & Ćirković, 2021; Schwartz et al., 2023). Further significant problems deal with philosophical questions about ETI. In particular, the ethics of METI—such as whether it ought to be done, who gets to do it, or what gets transmitted—have attracted considerable attention (see, e.g., Baum et al., 2011; Firth, 2023; Haramia, 2024; Haramia & DeMarines, 2019; Jebari & Olsson-Yaouzis, 2018; Korhonen, 2013; Smith, 2020; Traphagan, 2017).

Finally, it is worth mentioning that some philosophical discussions about space fall outside value theory. Most notably this would include the issue of defining *life*, as the question matters a great deal for astrobiology (see, e.g., Cleland, 2012; Mariscal & Doolittle, 2020), as well as epistemological and philosophy of science questions on astrobiological research or other space phenomena (see, e.g., Ćirković, 2018; Cowie, 2021; 2023; 2024; 2025; forthcoming; McMahon, 2020; Räikkä, 2024; Vickers, 2021; Vickers et al., 2023).

Now, while I have mentioned many questions and sources, this overview is not conclusive. It reflects my interests and predilections, and I could have noted many other papers and authors. Nevertheless, I hope to have given readers an understanding of the broad strokes for space ethics within academic philosophy.

Next, I shall argue for the relevance of space ethics and consider why we continue to see such increasing interest space ethical issues.

### 2.4.3 Relevance of Space Ethics

One can motivate space ethical research in at least three ways (Sivula, 2023). First, various space activities have already created ethical controversies, and so could benefit from voices in the social sciences and humanities, as the debates are often dominated by engineering and the natural sciences. Planetary protection and space debris are two examples in this regard. These problems raise complex issues that demand moral consideration, and so we need space ethicists to help us in this deliberation. We must weigh competing and important concerns, bring conceptual

clarity, and critically reflect while forming well-researched views, arguments, or theories on the matter.[24]

Second, as stated in the 'Concept' note of COMEST, in the 2024 'Ethical Considerations on Space Exploration and Exploitation':

> Space exploration has entered a breakthrough era. From 2025 to 2100, space travel is expected to become more accessible and commercialised, providing new opportunities such as space tourism, space mining and human permanent presence in space.[25]

Recent developments echo this sentiment. It may be overly optimistic, but the thought reflects a genuine revolution in the space sector, one that has been happening since the early 2010s. Since the start of the Space Age, which we usually mark by the 1957 launch of *Sputnik 1* (the first artificial satellite), space has been the exclusive playground of large spacefaring nations. There followed a decades-long 'quiet phase' in space activities, after the Cold War Space Race between the United States and the U.S.S.R. Things began to change in the 2010s as the space sector opened itself to private companies, and advances in technology (e.g., the miniaturisation of electronics) started to bear more fruit. These changes have given rise to the term 'New Space', to signify a shift in the global space ecosystem.

At the same time, the cost of rocket launches is dramatically falling. The cost of launches has varied drastically depending on various factors. To showcase the decreasing costs, we can note that in the 1960s and 70s, launching one kilogram (kg) of material into low-Earth orbit cost somewhere between $5,400 to $177,900, depending on the rockets used and the purposes for launch.[26] From the 1980s until the 2000s, the costs were between $5,100 and $73,100 per kg. In 2010, Space X's rocket Falcon 9 entered the scene, which dropped the costs at the low end down to $2,600 per kg. The costs decreased even more, to $1,500, per kg, when in 2018 the ship Falcon Heavy took flight (see Mathieu et al. 2022 for more on this). Launch costs are expected to keep falling, especially when the Starship spacecraft and the reusable Super Heavy booster rocket for Space X become operational.

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[24] Regarding the role and relevance of space ethics JS Johnson-Schwartz and Tony Milligan (2023) have suggested that it plays a crucial role in the following functions: *Balancing value considerations, enhancing decision-making, stress-testing concepts and frameworks,* and *keeping up on-going ethical engagement.*

[25] Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000390844. COMEST is an advisory body established by UNESCO in 1998.

[26] Prices are inflation-adjusted to the 2021 US dollar.

All such developments have reignited enthusiasm for space, novel space business,[27] and bold new plans for humanity's future in space. Evidence of this burst of interest can be seen with the launch of the Russian Luna-25 mission in 2023. A. C. Grayling (2024, pp. 96–97) has put the point this way:

> Luna-24 was a lunar surface sample mission flown in 1976. Nearly half a century, and in the midst of a highly self-damaging war, Russia's resolve to return to the moon indicates its anxiety about falling behind in the increasing space activity by so many players.

Another indication is the sheer number of objects in space. In late 2018, around 2,000 active satellites were orbiting Earth (Lawrence et al., 2022). Only six years later, though, there has been over a fivefold increase in this number: as of 30 June 2025, there are around 11,700 functioning satellites.[28] The rise is particularly attributable to SpaceX's megaconstellation *Starlink*, which offers internet to remote locations. As of June 2025, Starlink consists of over 7,800 operational satellites (Pultarova, 2025). The Starlink constellation continues to expand, and other organisations are planning their own megaconstellations. States around the world have already registered nearly two million new satellites with the International Telecommunication Union. Estimates suggest that by the end of the decade, there could be around 100,000 active satellites in Earth orbits (Lawrence et al., 2022).

These changes suggest that more space ethical questions, and associated problems, must be on the horizon. But scanning that horizon is insufficient; it is merely the first step. What is also needed is anticipatory philosophical and ethical scrutiny. It is usually easier to influence ideas, technologies, developments, norms, and laws when they are still in formation, rather than after they are implemented. This is because we may become trapped or locked-in into certain technologies, practices, relations, and behaviours. Breaking from these path-dependencies can be extremely difficult. On this point, Martin Elvis (2022) has used the concept of *founder effect* to think about space settlements. According to Elvis, legal and cultural regimes can be 'sticky' and long-lasting, and so we must keep in

[27] United Bank of Switzerland and Morgan Stanley, an investment bank, both forecast that the global space economy will be around 1 trillion dollars in 2040 (Crane et al. 2020).

[28] See: https://www.esa.int/Space_Safety/Space_Debris/Space_debris_by_the_numbers.

mind the foundations on which we build settlements beyond Earth. The founder effect applies not only to space settlements but also to many other issues both on the Earth and off (see Goldstein et al., 2023). For this reason, it would be wise to take a proactive approach to ethical questions, so that we can deal with them before it is too late. In the end, the decisions we make today set the stage for future developments which lead to certain space futures. Some of these are more desirable than others, and we ought to be working towards the desirable ones.[29]

This dissertation is an effort to this direction. One of the main claims of this study is that because directed panspermia presents a thorny, high-stakes choice, we ought to reflect on the ethics of it now rather than later (article I). If we start to consider whether seeding exoplanets with rudimentary forms of life is good or bad when the technology to do so already exists, we will be too late. When the practical know-how has already come, it is likely that someone will act on it (Soryl & Sandberg, 2025; article IV).

The third and final way to motivate space ethical research is through its theoretical value. Even if none of the space enthusiasm come to fruition, space ethics has theoretical value. We can think of space as a rich thought experiment, one that can provide new insights and a mirror against which we can reflect on traditional questions in a new context. Space is an opportunity to leave behind assumptions that we formed in an earthly context and history, to revisit old debates without the terrestrial baggage and to gain new perspectives on what has always seemed familiar.

Looking up to the stars has had this kind of by-product in science and in our understanding of the Earth. Milligan (2023, pp. 7–8) makes the point:

> Here, we may think about the identification of the greenhouse effect by James Hanson at NASA by analogy with runaway warming processes on Venus. Or, as a combination of science and cosmopolitical theory, we may think of the Gaia hypothesis that life on Earth is analogous to a single large biological cybernetic system. A productive analogy that emerged out of James Lovelock's life-detection work at NASA in the

[29] It is also important to note that some courses of actions can close off other options in the future. For example, there are strong arguments for favouring science over other space activities, especially in the case of Mars. Settlements and commercial activity on Mars may jeopardise science goals due to the contamination of pristine environments. Therefore, if we want both the benefits of science and other activities on Mars, science must happen first. Otherwise, we risk depriving us and future generations from remarkable scientific discoveries (Schwartz, 2019a; 2020a).

> 1960s, comparing our Earth's atmosphere with that of Mars. Neither of these theories were the result of looking only and directly at the Earth without placing it within some larger context. On a more historic scale, we might reflect upon the way in which Galileo's reworked concept of "systemi" has over the past century, migrated into our understanding of eco*systems*, and environmental *systems*. We routinely call upon the Galilean concept but with little or no acknowledgment of how we arrived at such a way of speaking and thinking.

Surely the same applies to philosophy. Benjamin Sachs-Cobbe (2018) has made a similar argument:

> Discussions about outer space have the advantage that we have very little attachment to anything out there. These ethical questions might therefore be some of the only ones humans can address with a large measure of emotional distance. For this reason, answering them might help us to make progress with Earth-bound issues […].

At the very least, thinking about space invites us to take up a cosmic perspective, which can shift our thinking by situating matters within a broader context. Anthony Weston (2009, p. 164) makes this same claim:

> […] whatever else may be said about space exploration, one basic feature is that it insistently forces upon us a larger-than-human perspective—in fact, a vastly larger-than-human perspective. For environmentalists, still struggling to inch our fellows even just slightly out of an anthropocentric point of view, achieving such a philosophical "escape velocity" is no small thing.

With these points in mind, I hope to have demonstrated an initial plausibility for the idea that consideration of space can yield novel insights into traditional philosophical debates. This should not be surprising; analogical reasoning and arguments from analogy are central methodological tools for philosophy, and so arguments, insights, and concepts may effectively transfer from one domain to another if the cases are sufficiently similar in their relevant aspects. However, whether the domain of space specifically offers something over and above domains such as artificial intelligence (AI), synthetic biology, robotics, or other emerging fields remains an open question.

This section has introduced space ethics and has traced some of its history to chart a need for the discipline. I now move to discuss intergenerational ethics and what this thesis has to say about longtermism.

## 2.5 Intergenerational Ethics and Longtermism

Intergenerational ethics is the study of our moral duties towards future generations. It studies the problems and nuances that temporality brings to moral theorising. At the core of this field is intergenerational relations and the question of what we owe to our posterity. Many important differences between intra- and inter-generational relationships challenge both our conventional ethical principles and the theories formed within intragenerational contexts. Indeed, John Rawls (1999, p. 251) has noted that justice between generations "subjects any ethical theory to severe if not impossible tests."

Intergenerational issues are increasingly important due to global environmental crisis, and so intergenerational ethics have gained growing attention in recent decades. Space activities also raise intergenerational problems, with Kessler Syndrome representing the perennial example: for most generations, it is collectively rational to use near-Earth space sustainably. Almost all generations view the outcomes of cooperation as better than whatever would emerge if use of orbits were unsustainable. For each generation individually, though, it is rational to *add* satellites to space: when every generation individually can choose whether to expand its use of near-Earth space or not, each prefers to expand, with little concern for sustainability and regardless of what subsequent generations will face. This diachronic collective problem leads to each generation passing responsibility down the line and making the situation tougher for those who follow. If the current generation is selfish and short-sighted, then space debris will increase, and future use of Earth orbits will be more expensive and more dangerous, and maybe even impossible, at least at some altitudes. This reveals the "tyranny of the contemporary" (Gardiner 2011), showing that orbital use is yet another domain in which present generations can dominate those to come.

The problem of space debris resembles the Tragedy of the Commons (Hardin, 1968), insofar as both are collective action problems regarding a valuable yet finite resource. But the coordination problem of space debris is largely intergenerational because the debris remains in orbit for so long unless it is actively managed, in contrast to the intragenerational dimension of the usual Tragedy. The generation-spanning nature of orbital

debris makes its resolution through increased communication and social intercourse, which is a standard solution to typical Tragedy situations, particularly challenging. Furthermore, we find a built-in asymmetry between generations: earlier ones occupy a position of dominance because of their significant causal influence over later generations, whereas future generations possess little leverage or reciprocal influence over their predecessors (see Gardiner, 2011).[30]

Space activities involve many other ethically pertinent intergenerational issues. For instance, certain activities on Moon or Mars may jeopardise future scientific objectives owing to the contamination of pristine environments. We might thus risk depriving future generations of important scientific findings. We might also consider future settlements off-Earth. Those living in them will be born into hostile space environments, thus raising issues of direct intergenerational interest. METI is another example. Any consequences that our messages to the stars may bring are bound to happen far in the future.[31]

However, in this dissertation my focus in narrower. I will focus on a recent turn of events in the intergenerational ethics discourse, that is, the idea of *longtermism.* Roughly speaking, longtermism is the idea that shaping the long-term future for the better ought to be a major moral priority now (Beckstead, 2019; Ord, 2020; MacAskill, 2022). Longtermism stretches the temporal horizon of our morality and proposes that we should be concerned for the *very* long-term future: say, one thousand to hundreds of thousands of years from now, and beyond. From this perspective, we might wonder what longtermism says about directed panspermia, and what the case of exoplanetary seeding reveals about longtermism itself.

A few distinctions are worth making at the outset. One can distinguish *axiological* longtermism form *deontic* longtermism (Greaves & MacAskill, 2021). Axiological longtermism claims that a greater part of the value lies in the future, and so most value will come from options that are best for the far future. This claim is about value only, though, and says nothing about what agents ought to do. Deontic longtermism makes explicit the leap from value to obligation or duty: *we ought to do* what makes the far

[30] Note the similarity to global warming caused by accumulating greenhouse gas emissions, which slowly change the Earth's climate.

[31] For those interested in these strands of thought, I want to point out that Stephen Gardiner and Mikko Puumala are assembling an edited volume on intergenerational space ethics to examine exactly these sorts of issues with the lens of intergenerational ethics.

future go best. Deontic longtermism is more controversial, because the axiological thesis might be correct with no corresponding obligation to do what is best. In many cases, perhaps, there are important deontic side-constraints rendering a deontic longtermism misguided. However, as I am sympathetic to the idea that a possibility to generate vast amount of value gives strong *pro tanto* reasons for action, I, for now, assume that axiological longtermism also implies some duties. In this dissertation, then, longtermism refers both to the axiological and to the deontic versions unless otherwise noted.

Hilary Greaves and William MacAskill (2021) believe that deontic longtermism also applies to non-consequentialists. They argue for this with a *stakes-sensitivity argument.* According to it, the axiological stakes of the long-term future are so massive that even the non-consequentialist should converge on the conclusion of choosing the option that is near best, which according to axiological longtermism is the one that makes the distant future go well. This argument has some initial credibility, as many believe that absolutism about duties or agent-centred prerogatives should be abandoned when a great deal is at stake and in such cases consequentialist logic should take over (see, e.g., Alexander & Moore, 2014). Despite the initial plausibility, though, one can question whether the axiological stakes are as high as Greaves and MacAskill claim, as David Thorstad notes (2023; 2024). I shall return to these arguments in Section 2.5.2.

Another distinction is between weak longtermism and strong longtermism (Greaves & MacAskill, 2021). According to strong longtermism, the "impact on the far future is the most important feature of our actions today" (ibid., p. 2). We can take this as the claim that the long-term future is the most important consideration in *most* of our important decisions today (see Lundgren & Kudlek, 2024).[32] As Greaves and colleagues (2021, p. 20) describe it:

> The claim, then, is that the moral value of our actions depends primarily on their consequences arising more than a century in the future. That means that the predicted short-run value of our actions should not weigh heavily in our decision-making. Instead, our choices

[32] Graves and MacAskill do not elaborate on what these decisions are, as noted by Björn Lundgren and Karolina Kudlek (2024); I do not attempt to resolve the issue here, but I assume that they include at least the decision of where to donate money and what career to pursue, as these are high-impact areas that they have focused on in their work.

> should be driven mainly by long-run considerations. Short-term effects matter, but they matter primarily as mediators of long-term effects.

'Weak' longtermism, or just longtermism without the 'strong' qualifier, does not make such sweeping arguments. Its claim is much more modest: it argues that concern for the long-term future is *a* moral imperative, among other things. That is, taking the far future into consideration in moral decision-making matters only in limited cases.

I am sceptical about whether strong longtermism is a reasonable ethical position, as we shall later see; for my purposes here, I take longtermism as the weaker thesis, unless stated differently. Moreover, I take it as a reminder of future's moral weight, and as an invitation to investigate ways to shape the future for the better and to test the limits of our obligations towards the distant future, instead of as a complete theory of our duties of beneficence.

With these preambles, we can now turn to the arguments for longtermism. The three premises making the case for both strands of longtermism are (see MacAskill, 2022; article II):

i. The future is vast.
ii. Morally speaking, the future matters.
iii. Current people can (in expectation) have a positive impact on the far future.

In what follows, I review the support for each premise and offer a few insights.

### 2.5.1 The Central Tenets of Longtermism

*i) The future is vast.* From any angle you take, the future seems vast, *in expectation*. Earth will probably remain habitable for complex life for around a billion more years (Wolf & Toon, 2015), and this does not even set the theoretical upper limit for Earth-originating life. If humanity settles other planets in our Solar System, for example, and eventually reaches out to other stars, the future trajectory of humanity and those beings descended from Earth could be unfathomably long.

More modestly, though, the origin of *Homo sapiens* dates to somewhere between 200,000 and 300,000 years ago (Snyder-Beattie et al., 2019). This may seem like a long time, but there are good reasons to think otherwise. We can see this in the history of life on Earth. From fossil records, the average lifespan of a mammalian species has been estimated at roughly 1

million years. Similarly, our predecessor *Homo erectus* managed to survive for about 1.7 million years (Ord, 2020, p. 85). With these reference points, it seems fair to assume that humanity may still have a long road ahead, and it is perhaps not overly optimistic to assume that we could survive for far longer than other mammals or hominin species. Humans currently occupy almost every corner of the Earth and have a high level of technological capability, which makes them better equipped to survive natural threats than other species (Greaves & MacAskill, 2021; MacAskill, 2022; Ord, 2020, pp. 85–86). In other words, humanity may be in its youth. Ecosystems or non-human animals could also have long-lasting futures, as I explore in article II.

Some may disagree. One could take a view of *hard technological determinism*, for instance, and claim that humankind is doomed because our technologies will inevitably lead to early extinction. I admit that this is possible but I struggle to see the plausibility. It is simply too pessimistic regarding our collective situation. As an anecdote, Derek Parfit (1984, pp. 453–454) seems to agree:

> The Earth will remain habitable for at least another billion years. Civilization began only a few thousand years ago. If we do not destroy mankind, these few thousand years may be only a tiny fraction of the whole of civilized human history.

Such a long potential future means that the expected number of future beings is enormous. Taking a conservative estimate, assume that humanity lives *in expectation* for 1.4 million[33] more years, and that the number of humans born per century is the same as the approximate human population today, or 8 billion.[34] The result is 112 *trillion* ($1.12 \, x \, 10^{14}$ or 112,000,000,000,000) expected future lives. For comparison, according to the Population Reference Bureau (Kaneda & Haub, 2022), about 117 *billion* (117,000,000,000) humans have been born *ever*, until now. That is almost thousand times less than the conservative estimate of expected future lives. On this estimate, in terms of human lives, all of our past is roughly worth one-thousandth of our potential future. And compared to the current world population, future generations hold in expectation 14,000 times more lives. So, arguably humanity's future may be enormous.

[33] If humanity lives 1.4 million years more, then our species' lifespan would come close to that of *Homo erectus.*

[34] The UN Department of Economic and Social Affairs (2019) has estimated that the 2100 world population will be 10.9 billion.

So far, I have discussed the future's size in terms of human lives. While longtermism has long had an anthropocentric orientation, this is not necessarily the only interpretation. In article II, I show that longtermism can be extended beyond humans to consider non-anthropocentric theories of value.

*ii) Morally speaking, the future matters.* For longtermism to make sense, one must have moral concern for the future. We usually care about what happens in the more distant future, even though in a straightforward sense that future does not yet exist; for example, people hope that future generations are well off, and some people take climate action because they see global warming as an issue of intergenerational justice. It is rare to see arguments claiming that the fate of posterity is a matter of indifference. Indeed, it is uncontroversial that the future matters, morally speaking.

Complexities remain, however. One arises from population ethics, which compares populations with respect to their goodness. The problem is that some views in population ethics, strictly speaking, do not care about posterity. For example, a *strict person-affecting view* may concern itself only with *existing* people. For such a view, an outcome is better than another only if it is better *for someone.* According to some person-affecting views, the interests of future people are ignored (Beckstead, 2019; Ord, 2020). Moreover, some hold an *asymmetric* view towards procreation (McMahan, 1981; Roberts, 2011). This is the idea that it is morally bad to bring into existence lives that are not worth living, while it is morally neutral to bring into existence good lives.

Both the strict person-affecting and the asymmetry view face many challenges. There is no need to repeat these challenges but what is relevant here is that if someone adopts the strict person-affecting view, they will not find longtermism convincing. The same may apply to the asymmetry view. Asymmetry posits that ensuring a good future is still important to the extent that we avoid bringing miserable lives into existence. Because the future is vast, we could argue that it is very likely to contain a great deal of suffering. Asymmetry would therefore prioritise actions that minimise future suffering. But it remains unclear how strong the resulting duties toward future generations actually are.[35] It is sufficient to say that the case for longtermism is strongest when one assumes a *totalist* view on population ethics, according to which "[…] the best outcome is the one in which there would be the greatest quantity of whatever makes life worth living" (Parfit, 1984, p. 387). I settle to say only this because the difficulty

[35] See Mogensen (2021), who argues that even asymmetry supports the view that the far future has overwhelming importance.

to construct a satisfactory population axiology is well known, and it is beyond the scope of this thesis to treat these questions comprehensively.

Now even if we think that the future matters, it may not be clear whether the *very far* future matters. Our moral intuitions, for one, might be silent about the very distant future. But the fact that we cannot relate emotionally to happiness, suffering, well-being, beauty, justice, and agony thousands of years to the future does not mean that those things are not real or do not matter when their time comes. A better explanation for the silence of our moral intuitions here is that our moral psychology, whence stem those intuitions, is unjustifiably myopic rather than that the long-term future does not matter morally. Of course, there remains the practical question of whether we can do anything for the far future with any certainty. That is, we tend to be bad at predicting the more distant future, and that failure may also affect our intuitions about it. I shall return to this point soon.

In addition, economists often discount future benefits based on how far away in time they are with a constant discount rate. For the far future to be important, one cannot subscribe to such temporal discounting: future benefits should not be dampened on the grounds of pure temporal preferences—at least when considering other more fundamental goods than commodities, such as people's lives or the well-being of sentient beings (Broome, 1994). This issue is crucial because, with long time scales, even modest positive discounting rates yield absurd conclusions. Let's see some examples:

> At a rate of pure time preference of 1 percent, a single death in 6,000 years' time would be vastly more important than a billion deaths in 9,000 years. And King Tutankhamun would have been obliged to value a single day of suffering in the life of one of his contemporaries as more important than a lifetime of suffering for all 7.7 billion people alive today (Ord, 2020, p. 255).

The same idea is captured in the following quote:

> Why should costs and benefits receive less weight, simply because they are further in the future? When the future comes, these benefits and costs will be no less real. Imagine finding out that you, having just reached your twenty-first birthday, must soon die of cancer because one evening Cleopatra wanted an extra helping of dessert. How could this be justified? (Cowen & Parfit, 1992, p. 145).

This obviously cannot be justified, and the sentiment is shared widely; among philosophers, we seem to find a relatively wide consensus for a zero rate of pure time preference (Broome, 1994; Greaves & MacAskill, 2021; Ord, 2020, p. 255).[36] Many thus conclude that the future matters morally and that the value of the future is not in itself diminished solely by virtue of its temporal location.

*iii) Current people can (in expectation) have a positive impact on the far future*. Even if we agree that the future is vast in expectation and that it matters morally, it is fair to question our ability to impact that future, as the effects of one's actions are usually harder to anticipate the more distant they are.[37] Despite this fact, our actions can have long-lasting effects that do not fade over time. The mitigation of extinction risks is a good example.

In expectation, humanity will persist for a long time if things go well. But if humankind becomes extinct then this will be the case indefinitely, and so lowering the risk of an extinction event has long-lasting effects. Many actions could mitigate these risks because the extinction of humanity may come about in various ways. Humans could face premature extinction owing to one or more of the following calamities: nuclear war, extreme climate change, ecological collapse, unaligned AI, pandemics (natural or engineered), asteroid or comet impact, nanotechnology catastrophe, or supervolcanic eruption. Presumably, other as-yet unknown risks also exist (Bostrom, 2013; Leslie, 1996; Ord, 2020).

Nick Beckstead (2019) notes that we have already done many things to reduce extinction risks: track asteroids near Earth, build underground bunkers, establish disease surveillance programmes and begin to takes some (if little) action on climate change. And we can do more. The current generation could invest in research on extinction risks, enhance pandemic readiness, increase civilisational resilience and prepare for global catastrophes such as nuclear war or supervolcanic eruptions, all with plans to safeguard humanity by, say, researching and developing resilient foods. The upshot is, as Jason Matheny (2007, p. 1340) argues, that "[e]ven if extinction events are improbable, the expected values of countermeasures could be large, as they include the value of all future lives." Thus, the expected benefit of such interventions exceeds many or most benefits of

[36] For a contrasting argument about a justified positive rate of pure intergenerational time preference, see, for instance, Mogensen (2022).

[37] No wonder that the timescales typically considered in futures studies and forecasting span only somewhere between five and fifty years (Nordlund, 2012).

near-term interventions (see, e.g., Greaves & MacAskill, 2021; Matheny, 2007; Mogensen, 2021).[38]

In addition to reducing extinction risks, there are other ways to positively affect the distant future. Mitigating climate change is such a case: even if global warming does not drive humanity to premature extinction, it could leave future people worse off for a long time. Shaping the development of AI might be another option (Greaves & MacAskill, 2021). The emergence of artificial superintelligence may lead to a situation in which humanity continues to exist but in some undesirable state because, perhaps, the artificial superintelligence has taken the world over and suppressed humanity for a prolonged period. A scenario like this would be an *existential catastrophe*, or an event destroying humanity's long-term potential (Ord, 2020), which may happen in ways other than extinction.[39] Avoiding those scenarios would arguably have significant positive value over the long term.

Greaves and MacAskill (2021) briefly discuss two other options. One is to establish longtermist funds to save money for later use. These funds would be used when actions that could sufficiently benefit the far future becomes available. The other option, a meta-option, would be to fund research on ways to leverage the future. The rationale is that there may be many ways to positively impact the far future that we have not identified yet. The deliberate seeding of other star systems with microbial and other simple organisms to ensure life's persistence could be one. The expected value could be enormous if life is valuable and rare in our galaxy (articles I and II).[40] In addition to the future being enormous and it being morally valuable, then, we can also shape it for the better—or so at least the argument for longtermism goes.

Note that the argument here concerns our ability to make a difference *in expectation* for the long-term future. We rarely know with certainty what will actually happen in times to come. We are clueless, as it were; and in the face of uncertainty, a rational decision-maker should maximise expected value. For example, we have good advance reasons to believe that going for a jog or a relaxing outdoor walk will benefit us, even though we do not know in reality whether they will turn out to be good for us. For all

[38] For concrete cost-effectiveness calculations, see, e.g., Matheny (2007); Millet and Snyder-Beattie (2017); Greaves and MacAskill (2021). These studies argue the importance of ensuring that the long-term future goes well. However, it should be highlighted that the moral mathematics behind them are not bulletproof (Thorstad, 2023; 2024).

[39] Greaves (2024) gives different definitions of "existential catastrophe."

[40] It could also be enormously bad, as explained in articles I and II.

we know, you might be hit by a car while jogging or step on a poisonous snake.

Nevertheless, many believe that our uncertainty towards the long-term future significantly undermines the argument for longtermism (e.g., Friederich, 2025; Lundgren & Kudlek, 2024; Thorstad, 2025). The claim is intuitive. In many cases it is hard or impossible to predict the long-term effects of one's actions. To address the challenge, scholars have emphasised the importance of *persistent states* (Greaves & MacAskill, 2021; O'Brien, 2024; Tarsney, 2023). Persistent states are states of the world that, if they come about, are highly likely to last for a very long time, and whose opposite is also persistent—in other words, the state would not likely arise without deliberate intervention. If we wish to have predictable long-lasting influences, we should identify persistent states we wish to avoid or create, in expectation. Extinction is one example, but so is the creation of a biosphere off-world, as I argue (article II).

Strong longtermism has also been criticised for other reasons, and next I review major arguments against it. I take them to suggest that the ambitions of strong longtermism should be scaled back. The arguments also motivate my choice to view longtermism as a valuable contribution to the discussion on intergenerational ethics, but which does not give the final word. Humans are myopic and many of our current problems stem from this short sightedness. One can hardly frown on efforts to pay more attention to future generations, although the case for strong longtermism does not seem as robust as, for example, Greaves and MacAskill (2021) have argued.

### 2.5.2 Criticism of Strong Longtermism

Mitigating the risk of human extinction is usually thought to offer the best case for strong longtermism (Bostrom, 2013; Greaves & MacAskill, 2021; Ord, 2020).[41] One can therefore criticise strong longtermism by meeting it at its own turf, and on epistemic grounds questioning whether the mitigation of existential risks is as important as has been argued. Thorstad (2023; 2024) takes this route of undermining the textbook example of longtermism.

Thorstad (2023) contends that, contrary to common assumptions, a high risk of human extinction for the next century diminishes the value of

[41] It should be noted that there is a philosophical discussion about what, if anything, makes human extinction bad (see, e.g., Fanciullo, 2024; Finneron-Burns, 2020; Frick, 2017; Lenman, 2002; Ord, 2020; Scheffler, 2013; Torres, 2023).

existential risk mitigation. The reasoning behind this claim is that high risk of extinction also implies that humanity's future will likely be short. This follows unless one takes the Time of Perils Hypothesis as correct. This hypothesis posits that the risk of existential catastrophe remains high for a relatively short period, but that it will fall very low if humankind survives this time of perils. Thorstad rightly notes, though, that this is a controversial assumption. Is there convincing evidence that we live in an particularly dangerous era? Why would risk decrease later?

Thorstad gives three possible supports for the assumption: 1) humanity's wisdom will grow to better manage existential risks, 2) investments in existential safety will increase as societies become richer; and 3) humanity will settle outer space and thus diversify the human presence in the cosmos. Thorstad finds them all unpersuasive, however. If the assumed enormous value of existential risk mitigation hinges on a questionable assumption, the uncertainty should make us re-evaluate the importance of reducing extinction risks—and so also the case for strong longtermism.

In another paper, Thorstad (2024) continues the attack on the claim that existential risk mitigation is fantastically valuable. According to Thorstad, proponents of longtermism have fallen for three mistakes in the moral mathematics of existential risk. The first is a problematic focus on cumulative rather than period risks:

> [T]he turn to cumulative risk misleadingly casts large reductions in period risk as small reductions in cumulative risk and puts too much emphasis on cumulative risks [faced by *all* future generations] that humanity today cannot effectively control rather than studying risks in nearby centuries that we can control (ibid., p. 128).

This mistake connects to the second, which is that of neglecting background risks not reduced by interventions in consideration: "this is a mistake because the presence of background risk constrains the effectiveness that risk-reduction efforts can have" (ibid., p. 124). As noted, if the extinction risks in general are high it follows that humanity's future will probably be short. But many of the models supporting the overwhelming importance of existential risk reduction have not taken this fact into consideration. Moreover, the remedy to this—the Time of Perils Hypothesis—is questionable, as we just saw.

The third mistake discussed by Thorstad concerns a questionable assumption about population dynamics. The human population may

decline in the future, and the change may be permanent; it is therefore misleading for longtermists to model the value of existential risk mitigation using high population estimates, such as the eight billion people per century mentioned above or indeed even higher numbers (see Greaves & MacAskill, 2021).

Collectively, these mistakes further suggest that the value for existential risk mitigation has been "inflated by many orders of magnitude" (Thorstad, 2024, p. 124). This implies that the class of situations in which collectives or individuals can substantially affect value over the long-term future is narrower than thought. The long-term impact of our actions thus becomes a less significant consideration, which weakens the case for strong longtermism.

Another option for criticising strong longtermism is to question its ethical presumptions. One can question consequentialism such that deontic strong longtermism does not emerge from axiological view without the stakes-sensitivity argument. But, as argued above, the stakes of the model case for longtermism might not be as high as some have assumed.

Even if a broadly consequentialist view is the most plausible ethical framework, we can still challenge the population-ethical assumptions behind longtermism. Totalism, or the idea that one population is better than another if and only if it contains a greater total quantity of whatever is valuable, gives the strongest foundation for longtermism. But this position is controversial because it entails the Repugnant Conclusion, a well-known problem for population ethics from Parfit (1984). Imagine two worlds, A and Z. In world A, people are living happy lives, whereas in world Z there are many more people than in A, but these people all have lives barely worth living. Totalism takes world Z as better if a sufficient number of people exist there such that Z's total utility exceeds A's. Many see this as absurd, hence the moniker 'Repugnant Conclusion'.

It is difficult, however, to form an alternative that avoids the Repugnant Conclusion without leading to other problematic outcomes. Some competing positions within population ethics, such as person-affecting or asymmetry views, see little value in mitigating extinction risks, and the non-identity problem (Parfit, 1984), where our actions influence not only the number and well-being of future people but also their identities, further complicates our moral obligations to future generations.

Our assumptions about population ethics may thus significantly weaken the case for both strong and weak longtermism. But the assumptions are especially problematic for deontic strong longtermism

when moral uncertainty is taken seriously.[42] If we are uncertain about which views in population ethics are reasonable, it is difficult to justify placing all our moral eggs into one far-future basket, as it were.[43]

Skepticisms about aggregation in ethics may also undermine strong longtermism, as many viable interventions for shaping the far future seem to entail the aggregation of very small benefits that together yield great total utility (see Curran, 2025). Imagine a philanthropist donating money for an intervention to decrease the probability of a future great-power war. Their donation is estimated to reduce the risk of a future war that would negatively affect two billion people by five parts in ten million. Here it is natural to think that the philanthropist is helping each individual by a tiny amount, even though in expectation they would be doing a lot of good (1,000 people avoiding a devastating war in expectation). The intervention gives many people a small chance to avoid great harm, thereby avoiding the catastrophic consequences of war.[44]

A similar structure for aggregating many small benefits into a large whole features in many interventions suggested by longtermism, because it is usually hard to bring about a long-term change with any certainty. But many find allowing the aggregation of small benefits deeply problematic for an ethical theory, as illustrated by T. M. Scanlon's (1998, p. 235) famous transmitter case.[45] Therefore, Emma Curran (2025, p. 3) argues that

[42] Moral uncertainty is uncertainty about evaluative and normative matters, as opposed to uncertainty about descriptive matters (see, e.g., MacAskill et al., 2020).

[43] Of course, this conclusion may depend on one's preferred approach to moral uncertainty. For instance, according to the My Favourite Theory approach (Gustafsson & Torpman, 2014), one should follow the moral theory in which one has the greatest credence. If that theory is totalism, the argument for longtermism remains intact. However, other approaches may yield different conclusions.

[44] For how longtermism fares with different theories of aggregation and different risk assessments, such as ex ante vs. ex post, see Curran (2025).

[45] Here is the transmitter room thought experiment:

> Suppose that Jones has suffered an accident in the transmitter room of a television station. Electrical equipment has fallen on his arm, and we cannot rescue him without turning off the transmitter for fifteen minutes. A World Cup match is in progress, watched by many people, and it will not be over for an hour. Jones's injury will not get any worse if we wait, but his hand has been mashed and he is receiving extremely painful electrical shocks. Should we rescue him now or wait until the match is over? (Scanlon, 1998, p. 235.)

Many have the intuition that we should save Jones immediately. They argue that the 15-minute break in the transmission is a minor inconvenience for

"deontic scepticism about aggregation not only undermines an obligation to invest in long-term interventions, but also the permissibility of doing so." Again, if we are uncertain about aggregation, then sweeping claims of strong longtermism may be imprudent.

Furthermore, many examples of how one might positively affect the distant future involve increasing the probability of a benefit by a tiny amount for many people. This is again due to the difficulty of bringing about long-term outcomes with much certainty. Given the enormous size of future populations, even a tiny chance of affecting how the long-term future goes is extremely important, and so the case for strong longtermism seems to depend on tiny probabilities of vast value (see e.g., Tarsney, 2023). The infinitesimally low likelihoods of immense value quantities drive the feeling of absurdity associated with the idea of strong longtermism. Many believe, in fact, that expected value reasoning errs in situations involving 'Pascalian' probabilities. In other words, there is something wrong with *fanaticism*, or the idea that we should take bets involving very small chances of extremely good outcomes.

There is nothing problematic in itself about considering small probabilities, but at some point they become so tiny that orthodox decision theory no longer seems reasonable.[46] The future as portrayed by longtermism seems to present such cases. According to Bostrom's (2013, pp. 18–19) "conservative" estimate, "the expected value of reducing existential risk by a mere one millionth of one percentage point is at least a hundred times the value of a million human lives." Making a sacrifice for such probabilities seems troubling because there is a huge chance of doing no good at all (Russell, 2023).

So where do we draw the line—what probabilities are fanatically small? Bradley Monton (2019) argues that, contrary to standard decision theory, tiny probabilities should be discounted to zero. Proposals for the threshold range from one in ten thousand to one in two quadrillion, and perhaps it lies somewhere in that range. Monton also thinks that the threshold is to some extent subjective. Small probabilities discounted to zero may offer a way to resist strong longtermism,[47] as only those interventions not hinging on tiny probabilities of enormous value would make the cut. As such

millions compared with the harm Jones faces, and therefore, we should not let the aggregate value of the two situations determine our action.

[46] For the contrary position see, for instance, Wilkinson (2022), who argues for fanaticism.

[47] Petra Kosonen (2022) argues that even discounting vanishing probabilities down to zero, we need not reject longtermism.

interventions may be harder to find, claims regarding the long-term future would be less sweeping and the case for strong longtermism would weaken. Altogether, these considerations make for significant theoretical challenges to strong longtermism. If Thorstad is correct to question the astronomical value typically attributed to existential risk mitigation, then in combination that would bolster the arguments too (Thorstad, 2024).

Finally, one can draw attention to the possible problematic implications of strong longtermism. It may be too demanding (see Mogensen, 2021), or it could have unacceptable distributive implications if it reallocates resources such that the worst off here and now are systematically neglected (see Hupfer, 2025). If axiological strong longtermism were true, the far future seems to present itself as a *real-life* utility monster (as opposed to an *imagined* case) creating immense amounts of value and turning resources into utility more efficiently than most actions available to us (see Nozick, 1974, p. 41; Parfit, 1984, pp. 388–389). It follows that, according to at least expected value maximising utilitarianism, societies should devote a significant amount of resources to extinction risk reduction and other projects that leverage the size of the future. Even on an individual level, one might have to devote most resources to improving the long-term future, such as what career to pursue and where to donate money (Greaves & MacAskill, 2021). Such a view is demanding and possibly absurd in light of the millions *currently* in need, and the personal projects we aspire to accomplish. It is as if "[y]ou are going to be mugged, as it were, by the future of humanity itself!" (Balfour, 2020, p. 121).

But if Thorstad is right about our assessing the value of extinction risk mitigation as too high, we do not face such troubling implications. Even so, if the theoretical consequences themselves are not especially problematic, one might still critique longtermism from a more sociological standpoint. After all, people might believe in or exploit the idea, regardless of whether it has any merit as a theory of beneficence. As Thorstad (2023, p. 400) notes:

> In addition to its philosophical importance, longtermism has had tremendous public impact through popular publications. It has also exerted a substantial influence on charitable giving, drawing money away from areas such as global health and poverty reduction and toward causes such as existential risk mitigation.

Émile P. Torres (2021a; 2021b) have even gone so far as to argue that longtermism is an immensely dangerous ideology. Maybe this is an exaggeration, but it is still serves as a good reminder that philosophy is not

done in a vacuum but, quite the contrary, it can often have real life impacts. As Mary Midgley (1992, p. 149) has said:

> Everything fertile and unpredictable is dangerous. Imaginative talk makes it impossible to disinfect thought by confining it in libraries for the use of licensed academics. Thought is incurably powerful and explosive stuff […].

These potential real-life impacts mean that (even) philosophers should pay more attention to the ethical dimensions of their research.

Let us pause to take stock. In this section, we have seen that the idea of strong longtermism has faced severe pushback. Where does this leave us? In light of its challenges, strong longtermism looks like a somewhat feeble position, and so I think that we ought to understand the view in terms of its weaker version. Discussions around longtermism should move away from the sweeping claims made by the strong version. This does not mean that the longtermist discussion is futile, however; in fact, the opposite is true. There is still value in the weaker idea, as that longtermism reminds us that in *some* cases, shaping the far future is morally extremely important. The number of such cases might be small due to the epistemic challenges involved. Moreover, we shall have to reason case by case, and there will be reasonable disagreement about the cases. Altogether, it does not seem like a good idea to direct *most* of our resources to improving the very distant future, even though *a* concern for that future can be legitimate moral concern *among others.*

### 2.5.3 Longtermism in the Context of This Thesis

Here I understand longtermism as its weaker version, which says only that we ought to give attention to the long-term consequences of our actions in *some* cases. This view underscores the future's moral significance and invites inquiry into how we might shape it for the better. It stands in contrast to strong longtermism, which contends that in *most* decision situations our choices should be guided by the far-future effects of our actions.

This study advances the discussion around longtermism in two ways. First, it injects environmental ethics into longtermist conversations. In article II, I draw attention to the fact that longtermist literature has thus far had a very anthropocentric orientation. In support of this critical observation, I demonstrate that although many have favoured a human-

centred approach to longtermism, there is conceptual room to extend the longtermist framework and encompass non-anthropocentric theories of value.

Second, I make a related argument that if environmental values are considered, directed panspermia presents avenues for promising interventions for longtermism, given certain assumptions that I discuss in articles I and II. Put differently, depending on how things turn out, either seeding lifeless exoplanets *or* preventing that seeding is overwhelmingly important from a longtermist perspective. This conclusion widens the scope of longtermism.[48] It suggests that longtermism is not only about mitigating existential risks but that it also has relevance beyond this narrow scope (article II).

It is worth noting that Thorstad's critical arguments about the value of existential risk mitigation do not apply to directed panspermia, so long as we assume that seeded biospheres, once established, are robust and long-lived. Because Earth's biosphere is more than three billion years old, there are some reasons to assume that this is indeed the case.[49] Worries about the Times of Peril Hypotheses, then, and cumulative risk, background risk, and population dynamics do not question exoplanetary seeding's value. Moreover, the issue of tiny probabilities may not apply here if the success rate of directed panspermia can be made sufficiently high. The issue of aggregation may not arise either, depending on how the value of exoplanetary seeding is understood and carved up. Nevertheless, I am not confident about how aggregation plays out in the context of directed panspermia, and so I leave this point for the future. There are, of course, other issues that may make directed panspermia undesirable, and thus give cause for caution, as argued in the articles of this dissertation (see also Section 3).

This section has introduced longtermism and given insights into recent associated debates. I argued that the strong version seems misguided, and so the view is best understood in its weaker form. I have just spelled out how longtermism is linked to this study. Now we turn to environmental ethics, the last field of moral philosophy notable in this thesis.

## 2.6 Environmental Ethics

[48] For a discussion on the scope of longtermism, see Thorstad (2025).

[49] This may vary by exoplanet, as a planet's habitability may be transient (Gros, 2016).

Here I discuss environmental ethics in connection to this dissertation. I have less to say about it because, of the three core branches of moral philosophy discussed here, environmental ethics is the most established and well-known.

As noted in the previous section, this study has inserted a pinch of environmental ethics into discussions about longtermism. Article II advanced what could be called long-term non-anthropocentric ethics (cf. Nolt, 2021) by extending the longtermist framework to consider non-anthropocentric value. Traditionally, Western ethical perspectives have been anthropocentric.[50] According to this human-centred view, only human beings are intrinsically valuable.[51] When environmental philosophy emerged in the 1970s, it criticised this orientation and began building grounds for the *moral status* or *moral considerability* of non-human entities (Brennan & Lo, 2024; Callicot, 1984; Palmer, 2014).[52] That is, they began to build a non-anthropocentric value theory.

The present study also rejects anthropocentrism. A popular alternative is *sentientism,* already defended by Jeremy Bentham (1996 [1789]) and later by Peter Singer (1975), which extends moral status to all beings capable of phenomenal consciousness. Ethical extensionism gives strong intuitive grounds for sentientism by identifying morally relevant capacities, like those for suffering and pleasure, in non-human animals.[53] If suffering is bad in humans—and it is—then suffering in animals must also be bad, the argument goes. In this way we expand the moral circle to include animals.

Some believe, though, that even sentientism is too narrow a view for moral considerability. For example, some philosophers argue that something can have a good of its own even if it does not *experience* it. Consider plants, the life form by analogy with which we appeal to the moral language of human flourishing. If they lack nutrients and water, it is bad for them, against their interests, so to speak. On this basis,

[50] This is not to say, of course, that *all* humans have always received equal treatment and moral status as there have been oppressed groups though out our history.

[51] A weaker form of anthropocentrism assigns significantly greater intrinsic value to humans than to non-human entities. In this view, even if non-human entities possess some intrinsic value, human interests would ultimately outweigh considerations given to non-human concerns (Brennan & Lo, 2024; Palmer, 2014).

[52] Something has moral status or moral considerability when we ought to take it *directly* into consideration in our decision-making.

[53] In principle, the extension is not restricted to animals. If, for example, AI systems can one day feel pleasure and pain, they would also merit moral status (Gibert & Martin, 2021).

philosophers such as Paul Taylor (1981) extend moral concern to all living things. Note, however, that granting moral considerability to wider groups does not necessarily entail that all of them are in fact given *equal* moral consideration. We can distinguish moral considerability, which one either has or does not have, from *moral significance*, which one can have more or less of. A scalar moral significance governs the moral weight something has in cases of conflict. As Kenneth Goodpaster (1978, p. 311) has said:

> Whether a tree, say, deserves any moral consideration is a question that must be kept separate from the question of whether trees deserve more or less consideration than dogs, or dogs than human persons. We should not expect that the criterion for having "moral standing" at all will be the same as the criterion for adjudicating competing claims to priority among beings that merit that standing.

Because of similar worries, that sentientism may miss something important about the moral reality, this study explores the normative implications of broader axiological frameworks in outer space and considers the possibility that individual non-sentient living organisms (biocentrism), or holistic ecological assemblages (ecocentrism), may also have intrinsic value.[54] However, I do not give a detailed defence of a bio- or eco-centric theory of value or moral status. As far as possible, I remain neutral with regard to metaethical standpoints about what is going on in talk about "intrinsic value" and its ultimate metaphysical underpinnings. This may be disappointing for some readers. Instead, I use moral uncertainty as an argument for taking those views into consideration. Given that philosophers and non-specialists alike often regard living entities or ecological wholes as deserving of moral consideration for their own sake, it is prudent to explore the normative implications of those views. Even modest credence in bio- or eco-centric views—say, 10% confidence—can reach substantial normative implications when combined with the immense potential value of actions such as directed panspermia (articles I and II). The argumentative strategy is modest but epistemically robust, as it allows accommodation for non-anthropocentric theories without overstating confidence in any particular axiology.

Because one of the motivations for directed panspermia is conserving Earth-originating life, this investigation also engages debates on the ethics

[54] The divide between individualistic and holistic theories of moral status is a fault line in environmental ethics, in addition to that between anthropocentrism and non-anthropocentrism (Palmer, 2014).

of nature conservation. For instance, article I observes that exoplanetary seeding could be taken as an extreme variant of assisted migration, that is, the controversial practice of intentionally relocating organisms as a part of a conservation approach.[55] Given the knowledge that life on Earth will inevitably end while Earth-originating life might persist elsewhere, we have compelling reasons to safeguard that life by exoplanetary seeding (article I). When framed this way, justification for directed panspermia closely parallels the motivations for preventing species extinction by assisted migration when they are threatened by climate change. As I note in article I, exoplanetary seeding and conventional assisted migration differ primarily in terms of scale: the distances for assisted migration are typically measured in tens or hundreds of kilometres, whereas those for directed panspermia would be measured in light-years. Directed panspermia also aims principally at preserving life (or certain types of lives) in general, rather than a specific species.

On the other hand, we might wish to preserve some extraterrestrial environments against anthropogenic influence, including seeding attempts. Perhaps planets have scientific, aesthetic, or intrinsic value that we ought to protect (see article IV). Similarly, the possible negative effects of relocating species into new environments have been a focal point in debates on the idea of assisted migration (see, e.g., Minteer & Collins, 2010).

Ecological engineering and restoration have also raised extensive debate in environmental ethics. One point concerns the role of *naturalness* in shaping the values and objectives underpinning conservation practices (for an overview, see Siipi, 2004). In article III, I examine terraforming through the lens of the concept of (un)naturalness. While Christopher McKay (2009) has suggested that terraforming Mars could be seen as ecological restoration (if the planet once had a biosphere), others have objected to terraforming by arguing that it would turn Mars into an artefact, something unnatural or even second rate (see, e.g., Lee, 1994). Indeed, terraforming involves invasive ecological interventions, exceeding even the most extreme forms of geoengineering currently discussed. I still argue in article III that the value of a Martian terraformed biosphere need not be significantly diminished by its unnaturalness. The crucial ethical questions on permissibility for terraforming relate mostly to the value of Martian abiotic environments, and how that value would fare after

[55] For environmental philosophy on assisted migration, see, e.g., Albrecht et al. (2012); Palmer and Larsson (2014); Sandler (2010); Siipi and Ahteensuu (2016). For terminology related to assisted migration, see Hällförs et al. (2014).

transformation. Although I leave much of this question for future investigation, in Article IV I argue that ethical considerations concerning inanimate environments are more significant for nearby celestial bodies, such as Mars, than for distant exoplanets.

It is all very well to repeat that abiotic environments encountered in outer space challenge conventional environmental ethical thought, which traditionally centres on the value of living entities (see Lindquist's remarks cited in section 2.4.2). Despite this "life bias" (Schwartz, 2019b, p. 354), it is essential to acknowledge the potential value of lifeless environments beyond Earth. This does not necessarily entail a hands-off attitude regarding space environments because just like we can distinguish moral considerability from moral significance, we can argue that while there are different sources of value associated with abiotic space environments they sometimes may be overridden if there is something more significant at stake.

A final major strand of environmental ethical discussion present in this study is wild animal suffering.[56] In the past decade, ethical discussions about wild animals have intensified. Animal ethics had previously concentrated on issues pertaining to animals under direct human control (Faria & Paez, 2015). One reason for new interest in wild animal suffering is the realisation that many have held an arguably romanticised view of animal life in nature. As Catia Faria and Eze Paez (ibid., p. 7) put it:

> It is commonly thought that, in nature, when free from any kind of human interference, animals enjoy happy lives, and that any problem they may face in that regard is actually due to human action. The truth of the matter, however, is at odds with this common belief. Unfortunately, reality is utterly unlike this idyllic picture of life in the wild.

Indeed, animals in the wild face many harms, from predation and starvation to disease, dehydration, parasitism, injury, and stress among other things. The most prevalent reproductive strategy in nature—where animals produce many offspring, most of whom lead brief lives—appears particularly cruel, as only a small fraction survive to adulthood and the majority may experience painful deaths shortly after birth. Thus, some have suggested that suffering dominates in nature, meaning that the lives of animals may be on the whole net negative (e.g., Horta, 2010; Johannsen,

[56] Environmental and animal ethics are sometimes separate, but I see the latter as part of the former.

2020; Tomasik, 2015).[57] The idea has a pedigree in Schopenhauerian pessimism: animals do not escape from the preponderance of suffering, sharing that misfortune with humans.[58] But we can separate that from a background commitment to pessimism about life as such, and held specifically as a claim about the lives of wild animals.

This possibility is significant for the present study. If terrestrial nature is characterised by widespread suffering, it is plausible that the same could occur on exoplanets following their seeding, as I argue in articles I and II (see also O'Brien, 2022; 2024; Soryl & Sandberg, 2025; Tomasik, 2015). This makes for a powerful objection against directed panspermia. Perhaps creating new worlds in this universe amounts to a moral calamity. Perhaps it is reckless to seed planets in the same way that it is reckless to impregnate someone and leave them and the child to their own devices (cf. O'Brien, 2022).

The issue also exemplifies what Mark Sagoff (1984) famously described as the "bad marriage, quick divorce" between Leopoldian environmental ethics and the animal liberation movement. As Sagoff (ibid., p. 299) notes:

> Nature ruthlessly limits animal populations by doing violence to virtually every individual before it reaches maturity; these conditions respect animal equality only in the darkest sense. Yet these are precisely the ecological relationships which Leopold admires; they are the conditions which he would not interfere with, but protect.

The point is that individualistic animal ethics readily conflicts with the more holistic approaches characteristic of environmental ethics (see also Faria & Paez, 2019).

Considerable uncertainty remains, however, about the actual extent of suffering experienced by wild animals. Some researchers challenge the claim that wild animals' lives are predominantly negative overall (see Browning & Veit, 2023; Groff & Ng, 2019; Palmer, 2022; York, 2024). It may be that claims about wild animal suffering are exaggerated, or perhaps the moral significance attributed to it is overstated; we need more research, as

[57] To better understand widespread wild animal suffering, Asher Soryl and colleagues (2021) have argued for the necessity of a new scientific discipline called *welfare biology*.

[58] Such pessimism about human life is sometimes taken to support antinatalism, which assigns negative value to human reproduction; see, e.g., Benatar (2006) and Häyry (2024a; 2024b).

the issue is a central question for the desirability of planetary seeding (articles I, II).

Against this background—cosmic footprints, planetary protection, directed panspermia from historical origins to contemporary debates, the emergence of space ethics within philosophical inquiry, intergenerational ethics, longtermism, and environmental ethics—we can now present this dissertation's central claims.

# 3 Aims and Claims

This dissertation's central aim is to shed light on the ethics of directed panspermia and the biological cosmic footprint of humanity. I wish to clarify the menu of options, that is, exhaust the space of possibilities for the ethics of disseminating microbial life to outer space. I also, map out the most crucial moral questions and evaluate answers to them. With different possibilities on the table, we can think more clearly and make better decisions. Sometimes this is the best philosophy can do: bring clarity.[59]

Because planetary seeding measures its potential downstream consequences in the millions of years, and can do either significant good or significant bad, I identify directed panspermia as a *moral high-stakes issue* (article I). By it, I mean an issue that has the potential to do grave moral harm or immense moral good. In consequentialist terms, it has the possibility of bringing about enormous amounts of value or disvalue. This can be either because of uncertainty toward consequences or uncertainty about their valence. Often, we may be highly confident about the consequences of a certain action, but still lack clear judgement about the moral value of these consequences. Directed panspermia involves uncertainty on both levels, as argued in this thesis.

As for humanity's cosmic footprint (see section 2.1 and article V), directed panspermia could create the largest and most consequential biological cosmic footprint that humanity's space activities might have. For this reason, I argue that the question of planetary seeding should be studied and debated carefully. One of the main research questions here

[59] Ludwig Wittgenstein (1922) gave similar ideas. In *Tractatus Logico-Philosophicus* Wittgenstein writes:

> The object of philosophy is the logical clarification of thoughts. Philosophy is not a theory but an activity. A philosophical work consists essentially of elucidations. […] Philosophy should make clear and delimit sharply the thoughts which otherwise are, as it were, opaque and blurred. (TLP 4.112.)

I like the sentiment, but I do not otherwise share the narrow vision that Wittgenstein sets for philosophy in that work.

relates to whether or not humanity should aim to seed exoplanets with life—or more precisely, under what, if any, conditions humanity is allowed or obligated to engage in directed panspermia.

Let me sketch a brief account of what makes directed panspermia so intriguing and morally significant. At the very latest, in about 1.6 billion years, the growing brightness of the Sun will sterilise all life on Earth, not human life (this happens much earlier), but all life. The idea that Earth-life will eventually die can be haunting. After all, there is a chance that life on Earth represents a unique kind of life in the cosmos (see Sandberg et al., 2018). Perhaps it is even worth appreciating the possibility that life as we know it is the only instance of life in our galaxy, or even in the entire universe. Because many complex creatures on Earth are sentient, a way of experiencing the world is lost. This means that what Simon P. James (2024) calls "lifeworld value" is lost.[60] By this James refers to the value associated with the unique subjective experience of a being, what phenomenologists often call *a life world.*

We can also question whether sentience, or the ability to feel and experience the world should be privileged from the point of view of the universe. Even though we may value sentience over other forms of being in the universe, it does not follow that other forms of life have no intrinsic value. It strikes me as a tragic loss, if certain types of life in the universe, whether sentient or not, are lost, because then one way of being in the cosmos is lost for good.[61] One 'being-in-the-world world' is lost. A certain niche for occupying the universe may be irretrievably lost if there is little life elsewhere.

This is similar to why a species extinction is sometimes tragic: "[…] distinctive way of going about the world, based on its history, ecology, genetics and phenotypic traits" is lost (Sandler, 2022, p. 2209).[62] This realisation should move us. It suggests a duty of *cosmic* conservation, or *cosmic* assisted migration, if you will. Of course, directed panspermia would not preserve the specific lifeworld values of beings here, but it may guarantee that *some* lifeworld values exist or emerge in our galaxy even

[60] See also Livermore (2024), who argues for the value of the diversity of subjective experiences.

[61] That is not to suggest that all extinction events are morally problematic. For instance, we may be content with the eradication of smallpox. Similarly, certain extinctions that occur as part of the natural course of evolution may not be morally tragic. My concern is not with the loss of any particular species, but rather with the irreversible loss of more general types of life.

[62] Ronald Sandler is speaking of human-caused extinction, but the point still applies.

after all sentience on Earth is gone. Additionally, the life sent from Earth would share a common origin with Earth-life, as all life on Earth does, and so on a minimal level some amount of 'our' niche of occupying the universe is preserved.

We can enhance this reason for protection by appealing to the value of diversity. Robbie Kubala and colleagues (forthcoming) have advocated such an approach:

> How much new instantiations of a kind of value contribute to the overall value of the world diminishes as there are further instantiations of that value. So […] [w]hen there are very few beautiful paintings in a world, each beautiful painting contributes a greater amount to the world's value. When there are very many such paintings, each contributes much less to overall value.

As it may be that the universe does not teem with the kinds of beings we associate with the value of life, spreading life elsewhere may contribute to the overall value of the universe beyond the value of its constituents.

The motivation for directed panspermia, as presented above, is not the only possible account. Other possibilities are explored in the articles of this dissertation. While this type of reasoning is addressed in articles I and II, it could have been emphasized more strongly, which is why I wanted to bring it forward here.

Even though the reasoning above gives a *prima facie* convincing reason for trying to safeguard the story of Earth's life, things are not actually that straightforward. The more specific claims I make are the following.

1. Longtermism can be expanded to incorporate non-anthropocentric value theories. If so, exoplanetary seeding may be among the top interventions that humanity could do to shape the far future for the better (article II). But an argument based on longtermist reasoning is not the only positive argument for directed panspermia, as illustrated above and in article I. Alternatives can orient around the idea of conserving value rather than maximising or effectively promoting it.
2. There are two central objections against directed panspermia: the risk of interfering with local biota, and the risk of increasing suffering. Their force depends on empirical and moral factors of which we are currently uncertain. In this dialectic we face a thorny choice: directed panspermia could be supremely good or

it could be supremely bad. I argue that, until we resolve this predicament, we should abstain from planetary seeding (article I).

3. I also consider reasons against directed panspermia stemming from the unnaturalness of novel ecosystem created after seeding (article III) and the value of abiotic environments (article IV). While these considerations can affect the moral desirability of directed panspermia, they are less concerning than the counterarguments presented above when weighed against the potential value of preserving Earth-originating life.

The last claim deserves further explanation. The reason why the risks of 1) interfering with native life, and 2) increasing suffering, are more devastating for directed panspermia is that if the central motivation for seeding exoplanets is to protect or promote *life*, then placing extraterrestrial *life* in danger directly conflicts with this rationale. This remains the case unless we value Earth's life above life elsewhere, but that would be suspiciously and arbitrarily Earth-centric.[63] One could even argue that it is *speciesists* if the differential valuing or treatment is based on nothing other than the organisms' place of origin (Cockell, 2007a). And if the suffering objection succeeds, it questions the whole premise for the seeding argument, which is that life, in general, is worth protecting. These two objections therefore most strongly challenge exoplanetary seeding.

The arguments from unnaturalness and from abiotic environments present cases in which values are diluted or in conflict. In articles III and IV, though, I explore reasons why the potential value loss might not be as significant after all in the case of exoplanetary seeding. In addition, even if the arguments fully succeed, such trade-offs in value can, in theory, be made reasonably if protecting life is considered valuable enough.

Before finishing this introductory essay, I shall make some methodological remarks.

[63] Cf. Earthism in Puumala (2024). For a discussion on *originism*, the view that lifeforms sharing a common origin with us are especially valuable, see Cockell (2007a) and Milligan (2016).

# 4 Remarks on Methodology and Approach

This dissertation is a work in practical and applied ethics: it addresses real-life moral problems by means of philosophical analysis and methods.[64] As mentioned above, this study's aim is to increase our moral understanding for humanity's biological cosmic footprint, by identifying and characterising the possibilities in exoplanetary seeding and analysing the ethical landscape arising therefrom.

To achieve this task, I have examined the question of whether humanity ought to aim to seed lifeless exoplanets with simple forms of life. I began addressing this question in article I by formulating the most convincing case in favour of directed panspermia. Then I moved to test, scrutinise, and modify the positive argument. Finally, I considered counterarguments against the constructed favourable case, examined their strength, and altered my judgements to form convincing, well-grounded, and coherent views on directed panspermia and on humanity's biological cosmic footprint more broadly. In this sense, the method is similar to testing, rejecting, or refining scientific hypotheses by experimentation. The aim is to come closer to knowing what we ought to do, *all things considered*. Essentially articles from I to IV are all in the process of doing this.[65] Article IV differs from the others in the sense that its function is more to show the larger context and relevance of the research done here and advocate for new governance responses to humanity's growing influence beyond Earth.

This approach resembles a standard method in moral philosophy, namely *wide reflective equilibrium* (WRE), which aims for coherence.[66] WRE

[64] Even though this study falls under practical ethics, there is no sharp dividing line between theoretical and practical ethics, and thus the distinction should not be exaggerated when it comes to methodology.

[65] Article III discusses terraforming Mars, but its results hold for exoplanetary seeding.

[66] Reflective equilibrium is based on Nelson Goodman's (1955) work but was canonised in ethics by John Rawls' 1971 classic *A Theory of Justice*, and further

treats moral inquiry as an exercise in bringing three levels of belief—judgements about particular cases, moral theories or principles, and background theories—into harmony. We do this by moving back and forth between judgements and more abstract level theories or principles, mutually adjusting both until we reach a coherent set of beliefs on all levels, and we know why and how they support each other. Additionally, background theories inform the process and must fit neatly into the equilibrium (Beauchamp & Childress, 2001; Brun, 2014; Kauppinen & Hirvelä, forthcoming; Knight, 2025; Räikkä, 2009).

Not just any belief or commitment counts as an initial input into WRE; they must be *considered*, or have some initial credibility.[67] Our judgements are considered when 1) we are well-informed on the subject matter, 2) the judgement is formed under favourable conditions (e.g., we are not intoxicated, angry, or in a hurry) and 3) we are motivated to reach the right verdict (Knight, 2025). Considered initial judgements ground WRE in something outside itself.[68] They may be on any level of generality from judgements about particular cases to more general rules or principles that apply to a wider range of cases to the highest level of generality namely ethical theory (Beauchamp & Childress, 2001; Brun, 2014; Knight, 2025; Rawls, 1999). The result is that if some part of an accepted moral theory clashes with our considered judgements, we must adjust either the theory or those considered judgements in order to achieve equilibrium (Beauchamp & Childress, 2001).

Because this study does not use WRE explicitly—as it is rarely done (Beauchamp & Childress, 2001; Rechnitzer, 2022)—an example will make the process more apparent. In article I, I begin with a considered moral judgement, namely that the continued existence of Earth-originating life is valuable. I also have principles, such as that there is a *prima facie* duty to promote value efficiently when one can do so without too high a personal cost. Background theories include knowledge from other fields, such as empirical and theoretical knowledge of space sciences, biology, and psychology. The inquiry is then a back and forth between these commitments at different levels by either accepting them, refining them, specifying them, or abandoning them. It is all done to discover a coherent position among our systematised and revised moral judgements,

developed as a method by Norman Daniels (1979) and others. Since then, it has been a topic of intense philosophical research (see, e.g., Brun et al., 2025).

[67] Or as Rawls (1999, p. 42) put it, considered judgements are "judgments in which our moral capacities are most likely to be displayed without distortion."

[68] It does not mean that they cannot be revised.

principles and background theories, while deliberating to gain moral understanding along the way. We also gain *dialectical justification*—that is, WRE helps us better justify our view to others (see Kauppinen & Hirvelä, forthcoming). WRE is an ongoing process, as Beauchamp and Childress (2001, p. 398) note: "We can never assume a completely stable equilibrium. The pruning and adjusting occur continually in view of the perpetual goal of reflective equilibrium."[69]

Within this larger framework of WRE there are *methodological tools* that are used for argumentation. These include conceptual analysis, conceptual clarification and conceptual engineering, thought experiments, arguments from analogy, modelling, arguments from moral uncertainty, and so on. The same holds true here. For example, articles I–IV all use thought experiments to elicit moral intuitions. Concepts are likewise being elucidated and analogies made to gain insights or draw conclusions. In articles I and II, I model how different plausible attitudes towards the value of extra units of life affects the moral desirability of directed panspermia, and then reach arguments from moral uncertainty.

This study aims to be neutral with respect to metaethical nuances, although it does assume, at minimum, that we have better reasons to accept certain moral claims over others. These reasons may be grounded on epistemic virtues the claims possess over less-justified claims; for instance, they may be based on or deduced from claims so basic that they are self-evident or intuitive in a way hardly anyone could question. These basic moral intuitions, what one might call "seemings," are such that they seem clearly true if one has grasped the concepts involved, or possesses an adequate understanding of the concepts (Audi, 2022). A simple example would be the claim that suffering is bad. This claim is obvious to anyone who understands the concepts of *suffering* and *bad*. This would be a *foundationalist* approach to justification.

Alternatively, a moral claim may gain credibility by being appropriately related to a set of beliefs that jointly enjoy some epistemically privileged status. This would be a *coherentist* approach to justification, which is at the heart of WRE. This study does not take a stance on the ultimate structure of justification, however. As I see it, a WRE framework

[69] There is a worry that WRE opens a door for relativisms, as there may be multiple equally coherent systems of beliefs (e.g., D'Agostino, 1988; Räikkä, 2009). I will not attempt to resolve this issue here, but, I will point out that, if WRE is understood as a way to gain moral understanding and dialectical justification instead of the kind of epistemic justification that bears on the truth of a proposition (see Kauppinen & Hirvelä, forthcoming; Räikkä, 2009), the blow of the relativism critique is softened.

can also accommodate claims that become credible on a more foundationalist basis, and so I do not rule out foundationalism. Some initial considered judgements might be credible because they are self-evident, or otherwise have some degree of foundationalist justification. The process of WRE then helps us to see how this initial judgement fits into a larger, messier picture of morality.

My approach throughout this work has been broadly consequentialist, but in line with WRE, I have avoided a strong commitment to any single ultimate ethical theory. I believe that it is methodologically useful, at least in practical ethics, to examine ethical questions from multiple perspectives. For instance, if the three main theories of normative ethics converge on a particular matter, that would provide a compelling argument in its favour. That said, the overall perspective adopted here has tended towards consequentialism. Therefore, further investigation into directed panspermia more strongly from other perspective, say, deontology, contractualism, and virtue-ethics would be valuable.

Indeed, I resist the so-called top-down method of applied ethics, where particular judgements, rules, and principles are deduced directly from some ultimate ethical theory, like utilitarianism or Kant's ethics (see Beauchamp & Childress, 2001).[70] Even if the world's moral ontology allowed for only one ethical theory or principle to be correct, the top-down method would still be insufficient because we do not know with certainty what the correct ultimate theory is. This study is therefore carried out broadly in the spirit of WRE, which aims to operate simultaneously top-down (from abstract theories to particular judgements) and bottom-up (from particular cases to rules, principles and theories). It seeks harmony between considerations across different levels of generality in ethics, and with relevant background theories.

Consequentialism remains a sensible starting point for embarking on a novel moral inquiry, however. As Rawls (1999, p. 26) famously claimed, any theory that disregards consequences is irrational, and so considering them offers a natural starting point for ethics. An additional reason to adopt a consequentialist perspective here is that matters of space ethics are often so-called public matters, as opposed to matters of individual morality. Thomas Nagel (1978) has observed that public morality tends to exhibit a more consequentialist character than private morality, and within appropriate limits Nagel takes the difference to be justified. Although Nagel's view is not an argument for a wholly consequentialist morality in

[70] The top-down method is useful for illustrating or revealing the implications of theories in particular cases, and so is a material part of most ethical inquiry.

public life, it can be taken to offer some justification for the methodological choice to take up a broadly consequentialist viewpoint in the context of this study.

# 5 Concluding Remarks

We humans are curious creatures—we "[…] polish the ever-larger lenses of our telescopes that tell us how ever-smaller we are" (Harvey, 2024, p. 28). Although we may be small compared with the vastness of the universe, we have thus far detected no signs of life beyond Earth. This could make us *cosmically significant*, as we might represent a beacon of value in a cold, empty, and indifferent cosmos (Kahane, 2013; 2021).[71] Our special status might also give rise to a duty of cosmic conservationism: a duty to seed habitable but currently lifeless exoplanets with simple forms of life. This idea of directed panspermia is explored throughout this dissertation.

This introductory essay has prepared the ground for the five articles on space ethics. Section 2 provided the background for the dissertation, framing it as a moral-philosophical inquiry into humanity's biological cosmic footprint. I also explained how this cosmic footprint is governed through planetary protection. I identified two key limitations in current planetary protection discourse, its narrow spatial focus and its tendency to serve mainly scientific interests, which we must reconsider as developments in science and space technology may enable new activities beyond Earth, such as directed panspermia. In Section 2.3, I traced the idea of directed panspermia from its origins to present debates, then situated it within the growing field of space ethics and emphasised its relevance amid recent New Space developments. Section 2.5 examined longtermism and gave its central argument, criticisms, and my conclusion that a weaker

[71] In her novel *Orbital*, Samantha Harvey has beautifully captured this tension between being either alone but attention-worthy or being trivial but having company. Harvey (2024, p. 29) writes,

> Maybe human civilisation is like a single life – we grow out of the royalty of childhood into supreme normality; we find out about our own unspecialness and in a flush of innocence we feel quite glad – if we're not special then we might not be alone. If there are who-knows-how-many solar systems just like ours, with who-knows-how-many planets, one of those planets surely inhabited, and companionship is our consolation for being trivial.

form is most defensible. Finally, Section 2.6 related environmental ethics to the dissertation's central questions.

Section 3 then presented the central claims. The primary argument can be summarised as follows: given uncertainty about the extent of life *beyond* Earth, and knowledge about an expiration date for life *on* Earth, there are compelling reasons for safeguarding Earth-originating life—either because we want to promote value efficiently (as per longtermism), or because we wish to conserve what is valuable. But there are also strong arguments against directed panspermia, including the risk of interfering with local biota and the risk of increasing suffering (article I). The objections' strength hinges on both empirical and moral considerations, both of which are uncertain at present. The uncertainty creates a difficult choice: directed panspermia might be an extremely beneficial act, or a profoundly harmful one (articles I and II). Humanity should therefore refrain from engaging in planetary seeding for now. Additional arguments against directed panspermia come from the unnaturalness associated with planetary seeding (article III) and the value of abiotic environments (article IV). These counterarguments are less concerning, though, than the two previous objections, especially when weighed against the potential value of preserving Earth's life in the cosmos.

Finally, Section 4 dealt with methodology. This thesis is a work of practical ethics, and, as such, it aims to increase our moral understanding of humanity's biological cosmic footprint. It does so by analysing the ethical landscape surrounding exoplanetary seeding. For this purpose, I have mostly used the method of WRE, a standard tool in practical ethics. This section also offered reasons for adopting a broadly consequentialist approach in this dissertation, while also encouraging further investigation into directed panspermia from additional ethical standpoints.

This study will by no means be the final word on the matter. I do hope, though, that it serves as kindling for an ardent discussion on humanity's cosmic footprint and the future of space exploration.

# Abbreviations

| | |
|---|---|
| AI | Artificial intelligence |
| COMEST | World Commission on the Ethics of Scientific Knowledge and Technology |
| COSPAR | Committee on Space Research |
| $CO^2$ | Carbon dioxide |
| ESA | European Space Agency |
| ETI | Extraterrestrial intelligence |
| GHG | Greenhouse gas |
| IDP | Interstellar directed panspermia |
| METI | Messaging extraterrestrial intelligence |
| NASA | National Aeronautics and Space Administration |
| NETT | The Modified No External Teleology Thesis |
| NFT | The Non-Fungibility Thesis |
| OST | Outer Space Treaty |
| PPM | Parts per million |
| SETI | Search for extraterrestrial intelligence |
| UN | United Nations |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UV | Ultraviolet |
| WRE | Wide reflective equilibrium |

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