The Technological Myth of Space Expansionism: Billionaire Futures in the Contemporary Space Age

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A Thesis in the Department of Communication Studies

Presented in Partial Fulfillment of the
Requirements for the Degree of Master of Arts
(Media Studies) at Concordia University
Montréal, Québec, Canada

August 2023

CONCORDIA UNIVERSITY
School of Graduate Studies

This is to certify that the thesis prepared

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Entitled: The Technological Myth of Space Expansionism: Billionaire Futures in the Contemporary Space Age

and submitted in partial fulfillment of the requirements for the degree of

Master of Arts (Media Studies)

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Abstract

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Samuel P. Garland

There is consensus among space advocates that we are entering a new era of the space age. The contemporary setting is characterized by the confluence of government space programs with tax-payer funds and commercial space ventures that are innovating emergent technologies. It is also heavily associated with the actions, dialogues, and envisioned futures of tech entrepreneurs Elon Musk and Jeff Bezos, billionaires who founded and own the private space companies SpaceX and Blue Origin. Earth's wealthiest individuals are determined to play a consequential role in exploring and exploiting other celestial bodies and extending human habitat into outer space. The multitude of ideologies, imaginaries, and discourses underpinning the project of space migration, from utopian to eschatological, can be condensed into one term: space expansionism. This thesis puts the burgeoning space economy and various theorized planetary futures into a historical context through conjunctural analysis. It finds that capitalism's pursuit of infinite resources and growth in the solar system, as communicated in and promised by space expansionism, is not only a dubious technological myth, but a dangerous one.

Acknowledgments

Thank you to my supervisor, Timothy Schwab, for his always valuable and dependable input and oversight of this thesis and several other projects over the years. I would also like to thank Dr. Charles R. Acland and Dr. Krista Lynes for being exceptional educators whose insight and experience is integral to the process. The COMS department has been an instrumental and generative place to study, work, create, and learn. I will always appreciate this.

A thousand thanks go to my friends for their curiosity and their feedback. I would especially like to recognize Chloe Dolgin for her unofficial peer review and Mason Martindale, who always opened his mind for discussion. Words cannot describe my immeasurable gratitude for my partner, Callaghan Lamond—thank you for every hour and every minute. To my parents, the one with inexhaustible support and the one with the unshakable plan, thank you for everything.

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Introduction

After it is burned to a crisp or even swallowed by the Sun, there will be other worlds and stars and galaxies coming into being—and they will know nothing of a place once called Earth.

— Carl Sagan, *Pale Blue Dot*

It is an inescapable reality that the Sun, the energy source for life on Earth and a deity known by many names, will eventually die. Five billion years from now, it will have run out of hydrogen to fuse in its core, and it will collapse (Frazier, 2019). Then, having matured into a red giant, the Sun's outer layers will expand to Mars' orbit. Earth may be pushed out of the solar system or pulled in by gravity, in which case, the only planet known to harbour life would be destroyed. Long before this cosmic event takes place, in only a billion years, the Sun's increasing luminosity will evaporate Earth's oceans (Scudder, 2015). A stream of charged particles will erode the magnetosphere and atmosphere, exposing the surface to unfiltered space radiation (Specktor, 2021). The Sun granted life in the solar system, and it will also eventually take it away, in whatever form that persists an eon from now (Siegel, 2020). For Earth, the consequences of the Sun's luminosity and expansion cannot be avoided. But what if humans, equipped with our consciousness, our intelligence, and our machines, were to escape?

For many, the natural answer to this question is for humanity to become a spacefaring civilization. We would branch out from our planet of origin and pass through interstellar space to construct artificial worlds or form settlements on celestial bodies orbiting stars different from our own. The Sun's transformation is a provocative anecdote of our fated solar system, regularly cited in the intersecting discussion of humanity's future and outer space. But, as an incentive for urgent innovation in space travel technology, the death of the Sun is irrelevant. While existential, the danger it presents to our species on this planet is so distant compared to contemporary anthropogenic crises that it is effectively a null point. In *Dark Skies* (2020), political scientist Daniel Deudney writes that the characterization of a condemned Earth is an effective way to represent multiplanetary expansion as a necessary undertaking for species survival. Further, the instrumentalization of technology in our modern, globalized, machine civilization has produced the "technological closure" of Earth, now regarded to be a finite and fragile frontier "with many limits to growth" (Deudney, 2020, p. 11). A new horizon has opened in its place: the unimaginable boundless enormity and infinite technical potential of the cosmos. Deudney refers to this discursive project in its totality as **space expansionism**.

A "subset of technological futurism," space expansionism is a metanarrative of humans and technology moving on a steady trajectory through history, set in a push-pull, life-death contract with nature (Deudney, 2020, p. 8). This up-and-to-the-right curve of social growth and technological advancement extends from nomadic peoples to urban industrialization as humans expand their habitat across geographies through exploration and colonization. Space expansionists concentrate on this pattern and, convinced of its efficacy, see its conclusion in outer space. "Given that the sun will eventually begin to die and render the Earth uninhabitable," Deudney writes, "the movement of humans across interstellar space is the ultimate step in the space expansionist ladder of ascent" (2020, p. 218). Expansionists advocate the feasibility and desirability of migrating to other worlds and star systems, because if humankind does blunder its departure, civilization will perish along with the Earth.

Despite being a conceptual bookend in the conversation of the planetary future, what the Sun's luminosity does not do (or should not do) is accentuate a need to extend our habitat into space anytime soon. Civilization as we know it is only a few thousand years old, reminding us that "modern humans, for all their technological prowess, represent an eye blink in the history of life" (Hayles, 1999, p. 284). The notion that conscious beings will inhabit this world in billions of years to witness the Sun's death throes is complete speculation. There are several known imminent threats for humanity to worry about and an unknowable unknown. Deudney's argument in *Dark Skies* is that forays into space pose a more significant and more immediate existential threat to Earthlings and catastrophic risk to the planet than they would alleviate. With a renewed interest in outer space from emergent and dominant actors in both nation-states and private ventures, such forays into and beyond orbit are increasing in frequency, and the technologies advancing in capability. A new epoch of the space age is just coming into being.

The persuasion of space expansionism, be it for settlement, scientific research, national claim, extraction for capital gain, or as an escape from the apocalypse, is engrossed with the notion of the future. Most of all, crewed extraterrestrial exploration is represented as the epitome of Western socio-technological futurity. It embodies the continuation of our species' machine civilization, in which the technologies we conceive are corporeal extensions of ourselves. Infrastructures and life support systems needed to actualize the habitat expansion are, at present, agreeable concepts and not extant realities. However, the institutions, corporations, and militaries that dictate activity outside Earth's atmosphere are competing and collaborating in multi-billion-dollar projects with the intent to speed things up. An outer space economy is well underway. When assessing the viability of industries, biopolitics, and cultural relativism in outer space, there are arduous and unavoidable physical-environmental factors and many intangibles. Utopias are certainly easier to conceptualize in abstract terms than they are to engineer in material ones. In this respect, the theorized prospect of people living and working independently of planet Earth is not sincerely measured in metrics of time—the rhetoric considers the matter an eventuality—but rather, in the space expansionist narrative, *the future is a place*.

Ursula K. Le Guin, the late author of acclaimed speculative fiction, recognized that to reach and conquer the future in any temporal sense is a falsehood. Nevertheless, it is persuasive enough to induce the idea that humans hold mastery over the present moment. Le Guin rejects the implicit assumption that the future is ahead; a direction or location we get to by means of forward movement. The Quechua-speaking people of South America's Andes Mountain range "see all this rather differently," Le Guin writes, "they figure that because the past is what you know, you can see it—it's in front of you" (1989, p. 142). For this Indigenous Amerindian perspective, the future is what lies behind, where it is only visible in brief glimpses. The forces of imperialism and globalization extend over geographies and cultures, so "we drag the Andean peoples into our world of progress, pollution, soap operas, and satellites, they are coming backwards—looking over their shoulders to find out where they're going" (1989, p. 142). As it was in the past and remains in the present, the terrain of the capitalist future is on uneven ground. If ongoing space projects and programs do not draw from multiple modes of being and knowing of space and time, the systemic issues of extractivism and exploitation in Earth's hegemonic structures will persist on other worlds. Decisions made and actions taken over the following decades in space exploration will dictate how our civilization extends its influence into space "with the potential to impact the environments we interact with on timescales longer than the human species has existed" (Tavares et al., 2020, p. 1). The present moment is particularly consequential for both terrestrial Earth and near-Earth space.

For this reason, the methodological framework for this thesis is conjunctural analysis. The method originates from Antonio Gramsci's *Prison Notebooks* (1971), later augmented in Raymond Williams' *Marxism and Literature* (1977) and Stuart Hall's *Policing the Crisis* (1978). A "conjuncture" refers to "what is happening" in the structures, institutions, and apparatuses of culture at a specific historical moment (Jefferson, 2021, p. 26). Analysis of the conjuncture, then, is an attempt to map the shifting topographies of power in society, "however fragile and temporary they may be" (Grossberg, 2019, p. 49). As a research methodology, conjunctural analysis offers an opportunity to historicize the political forces, contradictions, and crises of the present (Grayson & Little, 2017, p. 62). That entanglement of articulated relations and differences is where the conjuncture can be contextualized and understood (Carley, 2021, p. 59). From there, a cross-disciplinary conversation opens for what comes next.

This thesis scrutinizes the actions, or inactions, taken by the space industry, closely examining the dialogues communicated by its leading and most influential figures. The first chapter, as a literature review, intends to build a substantial base of knowledge in relevant topics across the various histories of the space age—from Russian Cosmism to the *Voyager*'s golden records. Chapter two historicizes the key actors, policies, and emergent technologies of the contemporary space industry, which increasingly relies on private-public partnership between governments and billionaire-owned space companies. This chapter examines pivotal political and industrial happenings in space programs, such as Constellation and Commercial Crew, that led to the unique positioning of the present moment. The third and final chapter aims to contextualize the positioning of the super-rich, namely Jeff Bezos and Elon Musk, in the changing geopolitical and economic terrain of outer space and disclose the underlying ideological sources that these individuals draw upon to communicate their envisioned futures.

In the pursuit of economic prosperity and the command of territory at any cost to its environment, there comes a realization that the natural resources and potential for energy on this planet are finite. As a result, the virtually endless potentialities of the future and outer space have morphed into one cohesive logic that acts as humankind's technological solution to the carrying capacity problem of terrestrial Earth. Without boundaries or limits, there is little need for sustainability or environmental ethics—they would only slow down the rate of forward progress into space and time. Space expansionism, as it is communicated and funded in the space projects of the world's wealthiest people in the conjuncture of the contemporary space age, embodies late-capitalism's deep-seated, dangerous, and flawed fixation with infinite growth.

Chapter One: Reviewing the Literature

Historical analogy is the last refuge of people who can't grasp the current situation.

— Kim Stanley Robinson, *Red Mars*

The Imaginaries of Space

Ideas about how life came to be and how it may end tend to fall into two ideological camps: science and religion. These two social forces that ask the big questions are considered to be formed based on contrasting ontological worldviews about the nature of the universe. However, John W. Traphagan (2020) writes that understanding religious practice and scientific research as necessarily at odds in space discourse is a product of Western intellectualism. An ideological discourse heavily associated with nineteenth-century settler colonialism and evangelization, it has also served as one of the roots of the essentialization and invalidation of Indigenous peoples and their beliefs. Traphagan writes that this codified notion of science and religion ignores a variety of epistemological frameworks and religious contexts from non-Western perspectives. As disparate cultural populations possess disparate conceptions of the nature of life *on* Earth, there will be fundamentally differing opinions on the nature of life *off* Earth, whether that be extraterrestrial, human, or post-human. In all its complexity and variety, the intersection of science and religion makes for some particularly poignant discussions about the future of life and death in the solar system and beyond.

Throughout the miscellaneous accounts of the space age, a degree of mysticism has grown around technology, both as a saviour of worlds and a promise of eternal life in the universe. As a result, space expansionism has become a quasi-religion itself. The deep roots of this ideology were seeded by Russian Cosmism at the turn of the twentieth century, most notably in the seminal work of Nikolai Fedorov and Konstantine E. Tsiolkovsky. Perpetually looking towards future technologies, generations, and social circumstances, Cosmism “assumes a mechanism of expansion” (Sosna, 2022, p. 261). The cosmist school of thought can be condensed to two major initiatives: active human evolution and mastery over the cosmos.

Fedorov, a librarian-philosopher writing in the late nineteenth century, started what is now referred to as the philosophy of the “common task,” an effort to unite all of humanity towards one true cause moulded by a convergence of religious, economic, biological, geographical, and aesthetic principles. It is based on Fedorov's understanding that as people decompose, their particles disperse throughout space. An extension of modern medicine’s capability to repair the tissues of wounds, the common task was to reverse that disintegration through restorative particle manipulation. In other words, Fedorov advocated for the end of death itself. His vision was that scientists would travel to the Moon and other planets, locating and reengineering the particles of human ancestors and, thus, resurrecting all the people who ever lived (Young, 2012, p. 49). This is the group, originating from all points in history, that will colonize other worlds. The Earth would then become mobile as a planetary spaceship, its climate regulated to produce resources that sustain a growing population of immortal beings (Scharmen, 2021, p. 15). To Fedorov, the material transformation of humans and the universe into what *ought to be* is humankind’s moral obligation to progress.

Fedorov was a mentor to Tsiolkovsky at Moscow's Chertovski Library, where Tsiolkovsky received his informal education. Inspired by the science fiction stories of Jules Verne, Tsiolkovsky wrote literature that incorporated space travel. Later in life, he shifted to theoretical research, developing mathematical formulas to actualize his scientific fantasies (Young, 2012, p. 149). Early in the twentieth century and later in his scientific career, Tsiolkovsky published an equation now known as the Tsiolkovsky formula—the equation used to measure the propulsion needed to reach escape velocity. Robert Goddard would be the first to conduct the first high-altitude flights in the late 1920s (Sagan, 2013, p. 116). By the 1950s, the United States and the Soviet Union were developing rockets as delivery systems for weapons of mass destruction. Tsiolkovsky directly inspired Soviet rocket engineer Sergei Korolev who oversaw the launch of the world's first artificial satellite *Sputnik 1* (the Russian word for satellite) in 1957 by a modified intercontinental ballistic missile (Scharmen, 2021, p. 69). It was a technological feat "second in importance to no other, not even to the splitting of the atom," that would have been celebrated "if it had not been for the uncomfortable military and political circumstances attending it" (Arendt, 1958, p. 1). The response of the rival geopolitical power, the United States, was to form a new federal agency: the National Aeronautics and Space Administration (NASA). Beginning with Cosmism and its ideological knock-on effects, *Sputnik* marked the genesis of the space age.

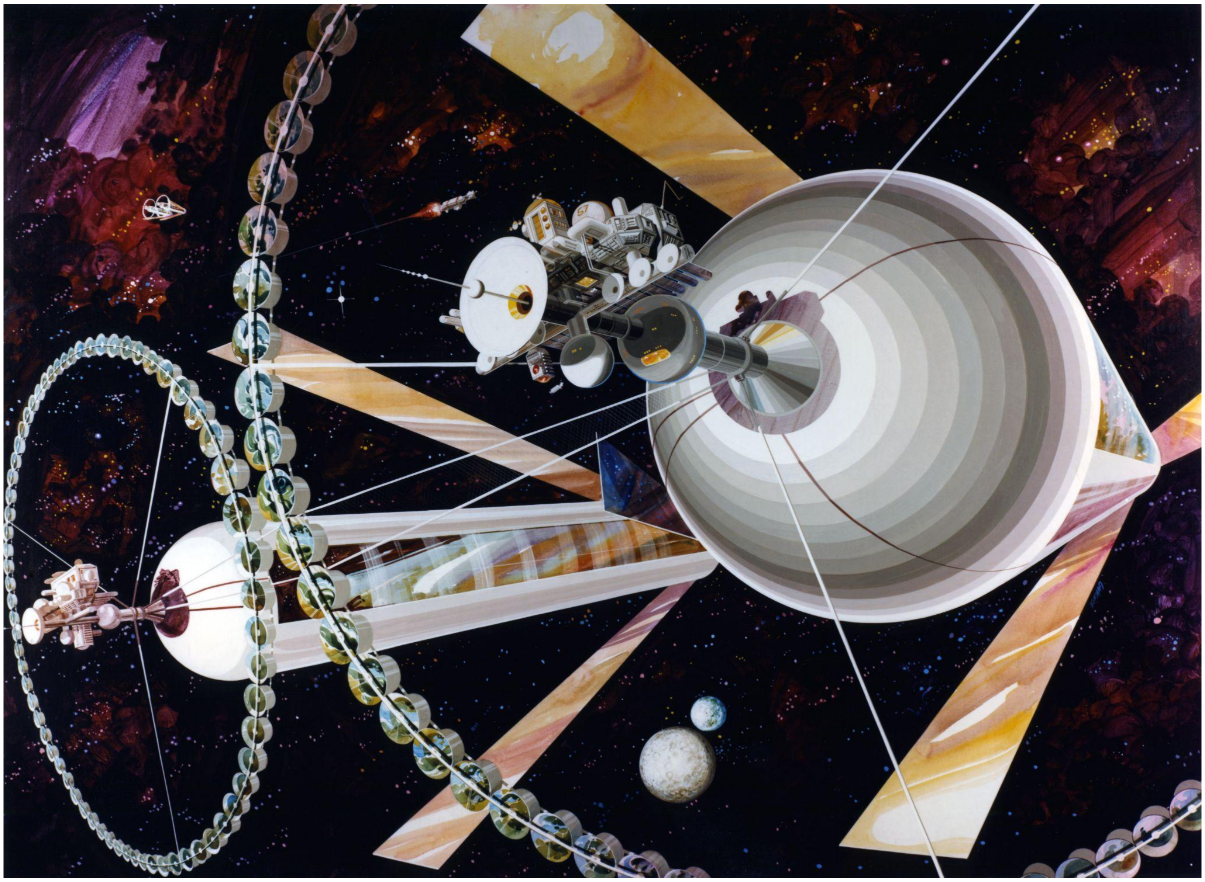
In Tsiolkovsky's non-technical writings, Christian faith and space science were one and the same. Like Fedorov, he saw the scale of things at its most minute and immense, believing in an "atom spirit" inherent in every particle of the cosmos. Tsiolkovsky understood the "macrocosm and microcosm to be structured upon the same organic principles" (Young, 2012, p. 152), but he saw the cosmos and its living matter through a hierarchical teleology. Lower life forms, or even material with dormant life, such as moons and asteroids, could have their atom spirits awakened to evolve into more complex and knowledgeable life forms. Tsiolkovsky detailed plans to eliminate primitive or imperfect life in the cosmos so that a higher being would be attained outside the material confines of the physical dimension. Through this genocidal expansion into the cosmos, Tsiolkovsky believed the universe would be guided to a state of perfection. As Fred Scharmen notes in *Space Forces*, the annihilative quality of Tsiolkovsky's philosophy puts his often-quoted phrase, "Earth is the cradle of humanity, but one cannot live in a cradle forever," in a different light (2021, p. 30). Russian Cosmism is a tenet of space expansionism, the overtones of anthropocentric religious perspectives becoming undertones of forgotten origin in contemporary discourse. Fedorov and Tsiolkovsky, in their formative yet esoteric imaginations, considered the issues of space migration and human immortality to be the mutually interdependent project of the cosmic future.

An anthropological lens reveals how space expansionism rhetoric abuts the human obsession with immortality—not only in the literal sense but through the figurative notion of being an interconnected part of a larger whole (Slobodian, 2015). Outer space promises the indefinite continuation of our civilization, assuring *symbolic* immortality. Expansionist discourse regards migration into space as an intuitive *telos* that humanity's technological progress has culminated in an ascent into the heavens. By this logic, if we cannot expand our habitat beyond Earth, then humankind's collective effort will have been for nothing. Thus, expansion into space is an assurance to circumvent inevitable annihilation. One such example is the narrative of the planet-killer asteroid—a deeply *existential* threat. Not only would the occurrence cause a mass extinction event for humans, but it would mean an end to all living things on Earth. What makes asteroids, or near-Earth objects, a perpetually looming threat is the inverse relationship between their size and the frequency in which they collide with Earth. Meteors enter Earth's atmosphere every day with little effect on its natural systems. However, major impact events of large asteroids happen hundreds of thousands to millions of years apart, fundamentally altering the planet. Risks associated with small collisions are negligible, but the risk of a large one is catastrophic. There have been five major extinction cycles in which most of Earth's life-forms perished, and "sure as day follows night, there will be more to come" (Kaku, 2018, p. 15). Impact events are regarded not as a matter of *whether* but *when*. The planet-killer asteroid narrative conveys that the alternative to immediate and well-funded action is not just an inevitable disaster but the non-existence of life itself.

Space expansionists contend that to preserve the light of consciousness, we must take humanity's eggs out of the one singular planetary basket. Incitations of fear are practical communication tools, and cosmic-apocalyptic ones are no exception. Not to say that space objects do not strike Earth at regular intervals in history—there are craters to prove it. Rather, the do-or-die message forwarded by space advocates has permeated the cultural zeitgeist. Reminders of death accelerate consumption at the societal level; material spending is a coping mechanism (Slobodian, 2015, p. 91). With mortality treated as a universal psychosocial problem, space travel technology has become a universal psychosocial solution. Fear of extinction on Earth materializes into an exaggerated vision of life elsewhere in the solar system—we can so readily picture a lasting future in outer space because we want there *to be a future at all*. Despite promises of the inevitability of technological advancement, there is no guarantee of life beyond Earth. That is why the conceptual closure of the planet where life evolved to exist is so dangerous. Techno-solutionism—engineering a fix to a problem while ignoring externalities—is regularly used to abate the fear of death or non-existence. Migration into outer space may be the largest project of symbolic immortality ever proposed.

Structures and infrastructures in space, like any construct on Earth, start with an idea. Tsiolkovsky was among the first to postulate that travelling to other planets was not the only way to conquer space. Artificial worlds could be manufactured by utilizing and industrializing the mineral resources of planets, moons, and asteroids. Later in the twentieth century, scientist J. D. Bernal crafted a hollow sphere design, giving the perspective of a world's surface inside-out. In *The High Frontier* (1976), physicist Gerard K. O'Neill expanded upon Bernal's plans with three new iterations that he referred to as "islands in space" (p. 63). The third of which, now known as an O'Neill Cylinder, scaled up the size and introduced two counter-rotating cylinders to simulate gravity, a concept first introduced by Tsiolkovsky. Island Three, a complete and sustainable ecosystem, was designed to house and employ several hundred million people. O'Neill imagined placing these free-floating megastructures in Earth's outermost orbit at Lagrange points—regions where the gravitational force of an object is in equilibrium with the Sun—to alleviate environmental degradation and shortages of natural resources.

Figure 1
Exterior View of a Double Cylinder Colony



Note. Cylindrical space colony painting by Rick Guidice at NASA Ames Research Center.

With an exponential rate of population growth but a finite capacity for energy creation on Earth, O'Neill argued that artificial worlds present an opportunity to disrupt an unsustainable system. In this regard, the "humanization of space" is a utopian ideal (O'Neill, 1976, p. 32). For critics, however, life in outer space is a "delusion, for it offers more growth and technology to stop the mess caused by growth and technology" (Munévar, 2016, p. 37). Capitalist ideology has effectively merged two into one: growth plus technology equals progress. Space megastructures are the projection of techno-solutionism in its most concentrated form: rather than mitigating the polluting effects of industrialization to restore Earth's ecology, to instead spur industry to construct new habitable worlds. Even as O'Neill wrote *The High Frontier,* author Wendell Berry described the space migration as a "solution to moral problems that contemplates no moral change" (1977, p. 36). Our terrestrial problem is the destructive and insatiable need to extract and consume resources for capital gain, not that we need access to more.

Theorists of space enterprises summon and discard modes of speculation to represent a desired technological future. Many of these ideas instrumentalize science fiction devices or become so entangled in imaginative frameworks that it is impossible to find the line between fantasy and reality. For instance, megastructures were a familiar setting in science fiction literature of this time, such as Larry Niven's *Ringworld* (1970) and Arthur C. Clarke's *Rendezvous with Rama* (1973). Everyone's ideas about space structures are fabrications; some of them are just packaged as stories with characters and a plot. Historian Alexander Geppert (2018) refers to the entanglement of speculative science and its narrative representation with the umbrella term "astroculture." The concept does not privilege scientific visions of the future over fictional ones. Instead, Geppert understands them as complementary forces that influence a collective imagination of space as the epitome of Western modernity and utopian possibility (2018, p. 6). We view the space age through an array of residual and emergent media. From mainstream images and texts created by propagandists to the cultural understanding of outer space in everyday life, astroculture appropriates past imaginaries of the future in their cultural context to elucidate the present imaginaries of the future as they unfold.

In 1999, aerospace engineer Robert Zubrin laid out his schematic of space exploration and planetary settlement in *Entering Space*. The book's chapters are structured on the Kardashev scale, as outlined by astronomer Nikolai Kardashev during the Sputnik era. The scale is a method used to classify a civilization's technological advancement into tiers based on its energy consumption. Kardashev defines a Type I civilization as one that uses all the energy available in its world, a Type II civilization harnesses all of the energy of its system's star, and a Type III civilization captures the energy of all stars in a galaxy. The scale stratifies levels of technological advancement needed for the macro-engineering of megastructures. At present, theoretical physicist Michio Kaku finds human civilization to be Type 0 but is undergoing a Type I transition as modernization and globalization foster a planetary culture. The internet, Kaku writes, is the first developed technology befitting a Type I civilization (2018, p. 284). Ultimately, Zubrin disregards Kardashev's metric of energy usage, prioritizing instead the habitable range of a civilization, the capability to conquer a planet, solar system, or galaxy. In this case, the settlement of Mars would be humanity's first leap into a Type II civilization (Zubrin, 1999, p. 124). Across the various interpretations, technology is invariably the determining factor of cosmic capability and the imagined possibilities for civilization's growth in outer space.

The Rhetoric of Space

A language and lexicon of space advocacy accompanies the wave of emergent space technology. In all its commercial partnerships, marketing campaigns, and lobbying efforts, the modern era has generated abundant discursive material wherein dated ideologies are repurposed in novel contexts. In a three-part series titled "Myth-free Space Advocacy," space philosopher James S. J. Schwartz reveals that several common arguments for space migration are premised on metaphors or anecdotes that are misleading at best, or demonstrably false at worst. Schwartz claims that space advocacy is saturated with rhetoric that characterizes exploration as an *essential*, not accidental, part of humankind's trajectory through history; an innate quality of people, past and future (2017a, p. 451). Apollo astronaut and vocal proponent of space expansion Buzz Aldrin, for instance, writes that it is due time for people to get "off this planet, and to realize our destiny in space," for this new era is a profitable enterprise, "not just in monetary terms, but also in the full realization of the human spirit" (2019, p. 3). The myth of innate exploration understands that humans are only limited by the thresholds of technologies. And as those thresholds are reached, we will again venture out into the great unknown.

In the “Myth of the Space Frontier,” Schwartz demonstrates how space advocates appeal to American settler-colonialism. Space frontierism relies on an interpretation of outer space as a “continuation, if not a logical extension of earlier geographies of imperial expansion and colonial domination” (Geppert, 2018, p. 4). It intends to revive the doctrine of *terra nullius* (nobody’s land) to grant the resources of space to industry, carte blanche. The discourse draws out the presumed rhetorical weight of the frontier metaphor, omitting the physical and cultural genocide of Indigenous peoples. Even so, space expansionists do not work too hard to separate their cause from colonial legacies. In his most recent title, *The Case for Space* (2019), Robert Zubrin finds that the “parallel between the Martian frontier and that of nineteenth-century America as technology drivers is, if anything, vastly understated” (p. 256). Here, territorial expansion is equated with technological progress: settlement begets challenge, and challenge begets innovation. In a timeline without movement into space, Zubrin writes, diversity will decline due to cultural homogenization and democracy will weaken. He predicts the “Martian frontier” will ameliorate many of Earth’s problems. Schwartz walks through many of Zubrin’s past claims, finding that his conception of the possibilities of space is often alleged without evidence or despite evidence to the contrary (2017b, p. 182).

As astrobiologist Charles Cockell writes in *The Meaning of Liberty Beyond Earth* (2014), the extremity of the space environment will present a dire challenge to extraterrestrial polity. That is, the paradox of individualism and collectivism—weighing the needs of one person against the needs of society (Cockell, 2014, p. 3). Pragmatic decision making and personal freedom will not always be mutually inclusive factors, during an inevitable emergency or otherwise. Fundamental affordances on Earth, such as the right to breathe without charge, may not be guaranteed in hazardous space environments. As astrophysicist Erika Nesvold writes in *Off-Earth* (2023), dissent from “oppressed populations is a powerful tool against tyranny, but only when it is allowed” (p. 152). Without rigorous planning, or perhaps even with it, vulnerable life support systems in space settlements will produce absolute conditions for despotism. The frontier metaphor sells the notion of liberty and opportunity, but the danger inherent to outer space complicates democracy far more than it bolsters it.

Astronomer Lucianne Walkowicz contends that if the scientists who engage with space exploration are not deliberate in the ethical dimensions of planetary protection *and* cognizant of Earth’s embedded histories, then they will “default” to exploitative colonialist ideologies that privilege capitalist enterprise over the common good (Martin et al., 2022). Space frontierism uncritically adopts the notion of manifest destiny, which expresses the eighteenth and nineteenth-century belief in westward expansion across the New World continent. Former President Donald Trump underscored the belief in his 2020 State of the Union Address:

> In reaffirming our heritage as a free nation, we must remember that America has always been a frontier nation. Now we must embrace the next frontier: America’s manifest destiny in the stars. I am asking Congress to fully fund the Artemis program to ensure that the next man or woman on the Moon will be American astronauts–using this as a launching pad to ensure that America is the first nation to plant its flag on Mars. (“Full Transcript”, 2020)

Trump invokes colonial narratives to frame expectations for Artemis, NASA's ongoing lunar program. Within this address, Trump also announced the creation of the sixth military branch, the U.S. Space Force. Imperialist terminology is essential to space expansionist rhetoric, which communicates a message of American exceptionalism in space (Koren, 2020). Zubrin doubles down on nationalistic sentiment with space militarism, making the case that the United States must assert total *space supremacy*, not simply technological superiority. As such, the U.S. should not only operate in near-Earth orbit "but be able to comprehensively deny this to others" through the deployment of "fighter satellites" (p. 59). The commercial space launch industry, he alleges, has presented an opportunity for Western superpowers to seize and control the ultimate high ground—the motto of the USSF is "Semper Supra" (Always Above). Zubrin and Trump's projected future in outer space is based on an astonishingly romanticized, if not willfully ignorant, perspective of the past in North America.

At the end of *The Case for Space*, Zubrin revamps Horace Greeley's adage of manifest destiny, "Go West, young man, Go West," with his version, "look up, young minds, look up" (2019, p. 302)—a statement directed towards the ever-inquisitive youth, but ostensibly not those of adversarial spacefaring nations. Assertions for innovation, especially in the private sector, depend on the revival of this problematic frontier analogy. It correlates outer space with the ethos of the Wild West—those who embrace its danger will reap its rewards: economic opportunity and political freedom. The doctrine of *terra nullius* is omnipresent in the dialogues of space enterprise; Mars is considered the *new* New World (Smiles, 2020). Language of the colonial project punctuates space discourse, illustrating that space futurism remains embroiled in the racist logics of settler colonialism. The often-touted ambition of space exploration is the betterment of humanity. However, as space frontierism makes clear, the future in space is meant for some groups of humanity and not for others.

American astronauts planted six flags on the Moon throughout the Apollo program, a symbol of nationhood and a tangible representation of territorial claim during the Space Race with the Soviet Union. For the past fifty-odd years, those cloth flags have been exposed to the unforgiving environment of the lunar surface—alternating fourteen days of unfiltered brightness and searing heat with fourteen days of frigid darkness (Spudis, 2011). Radiation from the Sun has, through a kind of poetic iconoclasm, bleached the stars and stripes of the American flags pure white. It is a reminder of both the sovereignty and extremity of outer space. Apollo 17 placed the sixth flag in 1972. It was the final Apollo mission, and the only one with a scientist onboard, Harrison Schmitt, an astronaut with a background in geology and not military aviation (Zastrow, 2022). Astronomer Carl Sagan writes that the Mercury, Gemini, and Apollo programs were not about science, or even about space. Predicated on a confrontation of national ideology and the omnipresent threat of nuclear war, the Space Race was a product of rival state-sponsored technical propaganda (Sagan, 1994, p. 102). There was, it seems, little to no incentive to lower exorbitant operational costs to make the lunar program sustainable. For historian Walter McDougall (1985), the unremitting militaristic antagonism and cultural competition between world powers "threaten[ed] to erode the very values that make one's society worth defending in the first place" (p. 13). This conundrum underpinned the Cold War space age. Sometimes, there are compelling reminders of what is at stake amongst the political-economic and technological tension.

On the trip to and from the Moon, the three Apollo 17 astronauts captured several photographs of Earth through the capsule window. One would come to be known as the *Blue Marble*, the first fully illuminated, colour photo of Earth taken by a person. It is now considered by many to be the most reproduced image in history. Naturally, all three astronauts claimed to have taken the picture (Reinert, 2011). Iconic of the environmental activism movement of the 1970s, it is regularly used to convey a message of fragility and unity on Earth; one blue marble in the lifeless void of space (NASM, 2009). As mass media objects, whole Earth photographs are often considered generative of a collective planetary imagination. *Blue Marble* makes invisible social constructs, showing no national borders or separations of religion and culture.

There is a term for the cognitive shift in global perspective felt when observing Earth from space. Coined by Frank White in the 1980s working alongside Gerard K. O'Neill, it is known as the Overview Effect. Through the testimonies of astronauts and cosmonauts who viewed the planet, White presented space as the next stage for elevated consciousness. Nowadays, he believes space migration will transform our collective identity: “your affinity as an Earthling is going to change. You'll have a different sense of who you are” (David, 2022). The step—or leap—between reaching orbit and reaching other planets is made naturally, but, at present, Apollo 17 was the last time any human travelled beyond low Earth orbit.

Figure 2
AS17-148-22727

Note. The original *Blue Marble* image as photographed during the Apollo 17 mission.

AS17-148-22727, the uncropped and unedited version of *Blue Marble*, shows Antarctica at the top, with Africa stretching down below. In the rendition released to the public, NASA reoriented the image to display north upwards and south downwards. North-up Mercator projection maps reinforce notions of colonial superiority, exhibiting a geographical hierarchy of the Global North over the Global South (Monmonier, 2004). Even though whole Earth photographs are heralded for subverting nationalism and cultural division, it appears that terrestrial biases still find their way in. There is no north or south in space, only gravitational pull. And, as evidenced by Apollo's white flags, radiation is indiscriminate. Outer space is indifferent to national and ideological claims, but as for the reverse, things become more complicated.

The Ethics of Space

For the majority of the space age, the legal guidelines for activity in outer space was defined by one document: the 1967 "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies," also known as the Outer Space Treaty (OST). Often regarded as the 'constitution of space,' it established the ground rules in international law for what can and cannot be done beyond terrestrial Earth. All spacefaring nations are signatories. The United Nations Office for Outer Space Affairs summarizes the OST's declaration of the following principles:

- the exploration and use of outer space shall be carried out for the benefit and in the interests of all countries and shall be the province of all mankind;
- outer space shall be free for exploration and use by all States;
- outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means;
- States shall not place nuclear weapons or other weapons of mass destruction in orbit or on celestial bodies or station them in outer space in any other manner;
- the Moon and other celestial bodies shall be used exclusively for peaceful purposes;
- astronauts shall be regarded as the envoys of mankind;
- States shall be responsible for national space activities whether carried out by governmental or non-governmental entities;
- States shall be liable for damage caused by their space objects; and
- States shall avoid harmful contamination of space and celestial bodies.

As the international legal framework for space exploration, the OST's articles designate the objects of space as the shared heritage of all humankind. It relies on the doctrine of *res communis* (common thing), meaning that celestial bodies such as asteroids, moons, or planets are the commons of all people and cannot be claimed by a nation or owned privately. What it does not explicitly mention are the resources within those celestial bodies. Journalist Peter Ward writes in *The Consequential Frontier* (2019) that the "ambiguous wording of the treaty creates a vacuum to be filled by self-interested interpretations" (p. 155). To the burgeoning commercial sector, the regulation and legal loop-holes of space governance matter a great deal.

While commercial parties operate under state authorization, they are not legally bound parties of the OST (Eijk, 2020). Space mining represents unbridled economic potential to national and subnational entities alike. A single metal-rich near-Earth asteroid, *1986 DA*, could be worth as much as $11.65T (Sanchez et al., 2021, p. 13). That is, before the influx of precious metals—more than the entirety of Earth's reserves—crashes the market. For the billionaires spearheading today's space industry (or the grass-roots startups of tomorrow), there are fortunes to be made and worlds to be gained. The difference between *res communis* and *terra nullius* is an essential point of legal-political contention in space expansionism; the industry relies on the capability to acquire and hold ownership over resources in extraterrestrial territory. For this reason, scholarly discourse is steadily forming around the issue of space ethics**.** Interdisciplinary researchers posit how space pertains to international law, planetary protection, and the good of humanity, if it ought to go in the first place.

Risk researcher Seth Baum (2016) draws from consequentialism, which determines if something is good or bad, valuable or dangerous, based on the outcome it produces. By this analysis, humankind should extend its presence into space insofar as it improves net value in the universe. For now, Baum believes humankind should maintain its focus and budget on reducing global catastrophe risk to keep our civilization intact on Earth. Because without any future, there can be no good future (Baum, 2016, p. 121). Ethicist Richard Randolph and planetary scientist Christoper McKay (2014) build their astrobiological argument for an ethics of space exploration based on a criterion of planetary protection and broadening life's diversity. In this framework, all life forms must be considered to have intrinsic value and not purely instrumental value—in other words, inherent worth versus utility. However, value is a subjective metric. Randolph and McKay assert that the pluralism of all religions and cultures on Earth is a belief in *life* itself. They believe that humanity could adopt a "cosmic Golden Rule" which would hold that "we should not treat inferior extraterrestrials differently from the way in which we would want superior extraterrestrials to treat us" (Randolph & McKay, 2014, p. 32). It is imperative, then, to prevent the destructive potential of forwards and backwards contamination, just as we would hope not to be contaminated. Precautionary environmental policies are needed to ensure that the exploration of other planets is done in a way that is "biologically reversible" if the second genesis of life is found independent of Earth (Levchenko et al., 2019, p. 8).

There are, consequently, acute ethical concerns about the proposals to terraform Mars. Still only theoretical concerning technological feasibility and access to the resources needed, the terraforming project entails the macro-engineering of the red planet's climate to better host terrestrial life. Technically, humans have only a demonstrated "track record of *unintentionally* changing a planet to be *less* hospitable to humanity and no practicable idea of how to do the reverse" (Walkowicz, 2018). Although the concept of terraforming resides in a legal-political grey area, cosmologist Chanda Prescod-Weinstein asks if humans "have the right to make that choice for the ecosystem" (Mandelbaum, 2018). Mars might not contain the conditions for life, but what if it does a billion years from now? After all, Earth revolved around the Sun for hundreds of millions of years before life formed into being. Altering the composition of other planets places exclusive value on human beings over other potential life forms—a concentrated case of anthropocentrism. If we are at risk of extinction by not expanding habitat to other planets, and terraforming Mars is genuinely the last resort, what makes humanity worth saving? Philosopher Kelly Smith (2021) refers to the perspective as "eco-nihilism," which dictates that if our civilization is to collapse due to an anthropogenic disaster resulting from ecological hubris or nuclear fallout, then so be it (p. 118).

If humanity cannot sustainably function on the planet upon which it evolved, then what evidence is there that it can sustainably function in outer space, with conditions hostile to our very biological composition? A matter of contention between health and environment, this issue embodies the problem of bioethics in space. Konrad Szocik and colleagues (2018) contend that reproduction is an imperative yet continually overlooked factor in the possibility of a Mars base. Chronic exposure to radiation while pregnant, in-vitro fertilization or giving birth in a reduced or zero gravity environment, abortion, consanguinity, and sexual selection—these are necessary issues to consider before expanding habitat to space (Szocik et al., 2018, p. 61). Many of these topics are enmeshed in fraught conversations across national policy and individual moral positioning. Haley Schuster and Steven L. Peck (2016) examine bioethical concerns of pregnancy for near-term interplanetary missions, finding temporary sexual sterilization of astronauts to be the most preferable option (p. 7). At this time, and likely for some time to come, no person has been born anywhere but on Earth. No presently planned missions are meant to last longer than one person's lifetime. But, if humanity is to become a multiplanetary species, that will not always be the case. Reproduction in outer space is a biological question mark, one that often gets reduced or excluded in the grandiose plans of habitat expansion.

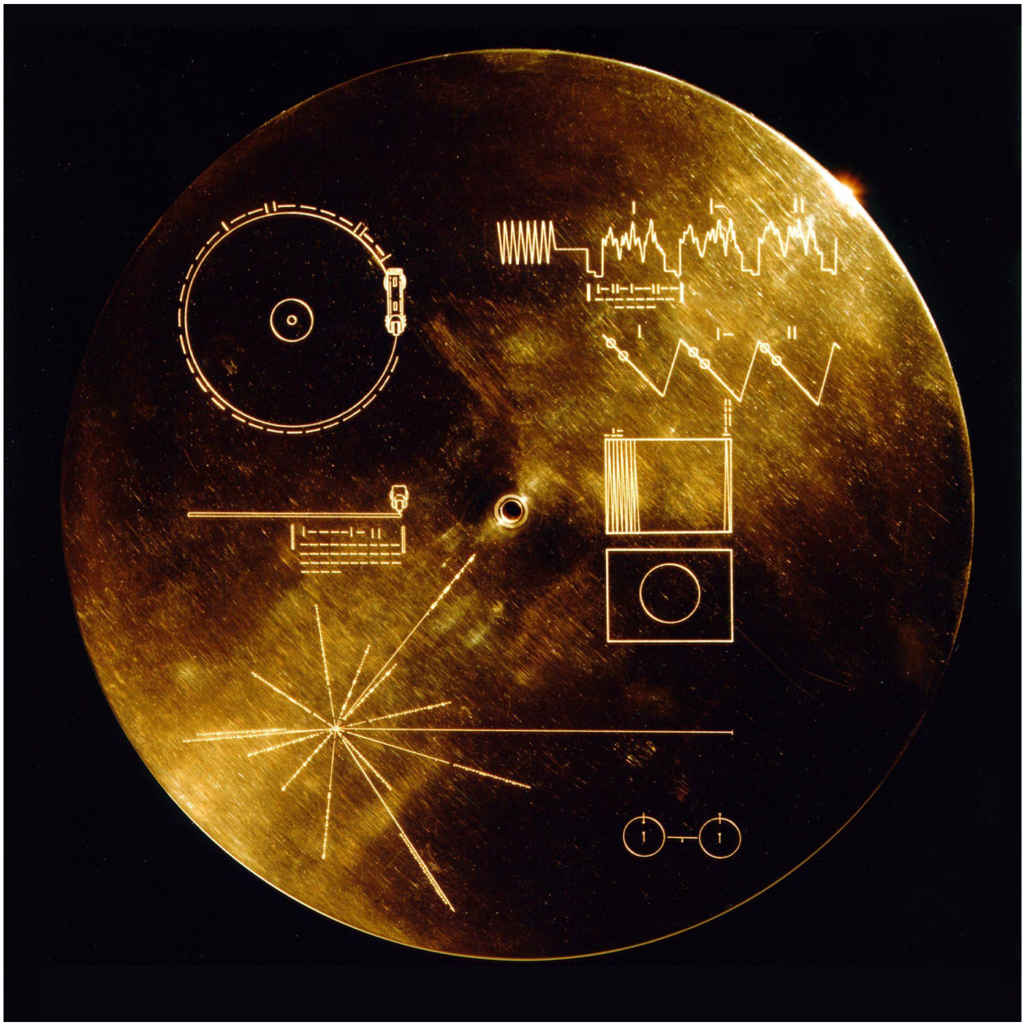
Another point of bioethical tension is the prospect of transhumanism, using technologies to augment human capability and survivability for the space environment. In this scenario, the genetic makeup is altered to make future humans more tolerant to the effects of microgravity or ionizing radiation. Ethicist Brian Patrick Green (2021) writes that there is no way to obtain informed consent from people who are yet to exist. As such, the manipulation of our evolutionary lineage would be considered a form of "proxy consent" (Green, 2021, p. 201). Can we ethically assume the authority to exercise such comprehensive power to influence the biology of our descendants irreversibly? We must consider this a moral question before a scientific one. The role of technologies will be a determinant of life and death in outer space. Philosopher Francesca Ferrando (2016) establishes the need for a posthumanist approach to space migration. Ferrando writes that the speculative narratives and actual possibilities of space travel and bio-technological adaptation are forging the beginnings of a paradigm shift in human-technology co-evolution (2016, p. 149). As desolate, dangerous, and unforgiving as it is, outer space asks us to define what it truly means to be human.

An answer to this question was offered in 1977, when NASA's Jet Propulsion Laboratory launched twin robotic space probes as part of the *Voyager* program to study the solar system. After gas giant planet flybys throughout the 1980s, the mission objective of the spacecraft transitioned to interstellar exploration. In 2012, 18 billion kilometres from the Sun, *Voyager 1* passed into the interstellar medium. It was the first artificial object ever to do so. Sister spacecraft *Voyager 2* became the second in 2018. Adhered to the side of each probe is a time capsule unlike any other, a golden phonograph record. In analog-encoded form, the record holds 155 images: a compilation of diagrams of physics and anatomy, visuals of the solar system, landscapes, architecture, and infrastructure from around the world, a range of flora and fauna, and people, just as diverse. The remainder is auditory, containing music from different regions and eras, a series of natural noises, and greetings in 55 languages (Dick, 2007).

Information on the discs was selected for two possible audiences that could intercept the spacecraft: an advanced extraterrestrial civilization or those of Earth origin in a distant future (Skibba, 2022). Even travelling at tens of thousands of kilometres per hour, the *Voyager* probes will not encounter other star constellations for tens of thousands of years. When played correctly, the disc takes one hour front-to-back. In that hour, messages on the golden record intend to communicate—to potentially incomprehensibly different conscious beings—who humans are. Monuments to life and technology, *Voyager 1* and *2* will long outlast the planet of origin. Astronomers have calculated that the probes could traverse interstellar space for trillions of years (Huchingson, 2022). Envoys of Earth, these robots may be the closest thing to immortality that humanity can possibly achieve. In a billion years, when the Sun's luminosity has evaporated Earth's liquid water, the sounds and visuals on those discs will remain. Even if humankind is to perish without having explored, migrated, settled, conquered, and expanded into space beyond the solar system, *Voyager* and the golden records hold evidence that our civilization and our home planet ever existed at all.

Figure 3

Voyager Golden Record Cover



Note. Symbols depicted on the cover show how the disc is played and its origin in the universe.

Chapter Two: Historicizing the Contemporary Space Age

But it was in science that the abstractions of capitalism came in the long run to play an even greater role and to bring an even greater reward.

— Lewis Mumford, *The Myth of the Machine*

Artemis & the Self-Licking Ice Cream Cone

On December 11th, 2022, precisely fifty years after the Apollo 17 lunar module landed on the Moon, NASA's Orion capsule reentered Earth's atmosphere and splashed in the Pacific Ocean. 25 and a half days prior, it lifted off from the Kennedy Space Center atop the Space Launch System (SLS) rocket, a heavy-lift expendable launch vehicle designed to facilitate deep space missions. The rocket's core stage and two outboard solid rocket boosters generated 8.8 million pounds of thrust, exceeding the power of Apollo's Saturn V (Wall, 2022). In its first integrated test flight, SLS blasted through the atmosphere and delivered the uncrewed Orion spacecraft into orbit (Harbaugh, 2022). The spacecraft then performed a trans-lunar injection, a propulsive maneuver which sent it on a trajectory to the Moon. Orion completed one lunar flyby, transitioned into distant retrograde orbit for six days, and passed by the lunar surface for a second time, burning its main engine and using the Moon's gravitation to set its course home.

After travelling over 2.2 million kilometres through space, the return of the spacecraft intact marks a resounding success of the first phase of the Artemis program, Artemis I. One of the leading technical objectives was to test Orion's heat shield during reentry for Artemis II, the crewed lunar-flyby set to launch in 2024 (NASA, 2022a). This mission will send American astronauts Reid Wiseman, Victor Glover, Christina Koch, and Canadian astronaut Jeremy Hansen to the Moon—humanity's first venture beyond low-Earth orbit since 1972 (Chang, 2023). Building from the two precursor missions, Artemis III will land two astronauts, including a woman and a person of colour, at the Moon's South pole region in 2025. By most indications, this timeline will likely not be met. Artemis, started under the Trump administration and continued by the Biden administration, is NASA's return to crewed lunar exploration that originated with Apollo over half a century ago. This time around, in partnership with the European Space Agency, Japan Aerospace Exploration Agency, and the Canadian Space Agency, America intends to establish a sustained presence on the Moon with a lunar base and orbiting space station, manufacturing and experimenting with technologies for the long-term objective of putting astronauts on Mars. This is, more or less, the logline of the Artemis program.

With the retrieval of Orion, NASA is evaluating the spacecraft's heat shield, analyzing its biology experiment payloads, and harvesting and recycling the avionics boxes—the "brains" that run the software—to be refurbished and recertified for Artemis II (Clark, 2023). Of the entire SLS stack standing 322 feet tall, the capsule's avionics boxes are the only hardware slated for reuse; the core stage's four RS-25 engines and solid rocket boosters were discarded during launch and are now located on the seafloor (Pearlman, 2022). This is what makes expendable launch systems *expendable*. Despite SLS being a single-use technology, the cost of the Artemis program to American tax-payers has been enormous. In November of 2021, the NASA Office of Inspector General (OIG) audited Artemis' budget and schedule, finding that the agency did not have a credible estimate of the comprehensive cost of the program. The report projected that between the fiscal years of 2012 and 2025, Artemis expenditures will reach $93B (NASA & OIG, 2021, p. 21). For at least the first four Artemis missions, a *single launch* of SLS is estimated to cost $4.1B—a figure eight times greater than what officials pledged in 2012 (Minter, 2022). The cost-per-launch calculation is based on this distribution of funds: $1B for the Orion capsule, with an additional $300M for the European Service Module, $568M for operations and maintenance of the Exploration Ground systems, and $2.2B for SLS and its boosters (NASA & OIG, 2021, p. 24). In conclusion, the audit determined that if NASA does not significantly reduce and accurately report production costs of the near-term SLS/Orion missions, there will be considerable difficulty in sustaining Artemis long-term.

With this budgetary trend, deep space exploration with Artemis may not be tenable, and NASA does not have an easy fix. SLS and Orion are projects with a developmental lineage that traces through policy and politics for over a decade. In this same time frame, innovation in the commercial sector by private companies such as SpaceX and Blue Origin has radically transformed the terrain of the space industry. Coinciding with this wave of advancement, SLS has become a contentious subject in human spaceflight. Most of this tension can be boiled down to one principal technological driver: rapid reusability. Reusable launch vehicles can deliver a payload to orbit, return to Earth, and be reflown to space again. Not having to manufacture new parts for each lift-off has dramatically reduced the cost of launching rockets.

To the traditional space industry, reusable heavy-lift rockets are both the saviour and the harbinger of death. Economically, outer space is made more accessible than ever to nations and corporations alike. But a long-standing symbiotic relationship between modes of government and legacy aerospace companies has been destabilized. That is why the early Artemis missions are at odds with the contemporary space age in which they are set: SLS is an expendable launch system which suffered several years of delays and is massively over budget (Dinner, 2022a). In the era of reusability, why is NASA taking what seems like a backwards step to pursue an unsustainable program organized around a rocket teetering on the edge of obsolescence? There may not be a definitive answer, but it is unequivocal that politics is a determining factor. To understand how the Artemis campaign is embedded in administrative and legislative power structures, it is necessary to take a glimpse into its past.

Apollo 18, 19, and 20 were missions to the Moon that never happened. With the discontinuation of the Apollo program after budgetary constraints in 1970, NASA sought a cheaper and partially-reusable Space Transportation System—known as the Space Shuttle. Akin to a traditional rocket, the Shuttle's Orbiter Vehicle was launched vertically with the external fuel tank, two recoverable solid rocket boosters, and three RS-25 engines. However, upon reentry into the atmosphere, the winged orbiter would glide to a horizontal landing on a runway. The world's first orbital spacecraft designed to be reflown, Shuttle was both a spaceplane and a rocket. *Columbia*, *Challenger*, *Discovery*, *Atlantis*, and *Endeavour* flew a combined 135 missions from 1981 to 2011. Although the Shuttle system launched payloads of historical scientific importance, such as the Galileo and Magellan space probes, the Hubble Space Telescope, and many components of the International Space Station (ISS), its central objective of affordability was never realized. NASA estimated the cost of the whole program to be $209B, indicating a $1.6B cost-per-launch (Wall, 2011).

After several decades of operations that sent civilian, military, and commercial payloads to low Earth orbit, the states of Texas and Florida had each amassed large, specialized workforces required to build and constantly service the spacecraft (Dreier, 2022). In 2003, Space Shuttle *Columbia* disintegrated as it reentered the atmosphere, killing all seven astronauts on board and exposing a fundamental design flaw. During launch, foam insulation had dislodged. The debris damaged the orbiter's heat shield, dooming the crew. American spaceflight was grounded, but its fate was still up in the air. In response to the *Columbia* disaster, President George W. Bush announced "The Vision for Space Exploration" in early 2004—NASA's newfangled plan for exploration of the solar system and beyond, which came to be the Constellation program. The primary objectives were to retire the Shuttle after completion of the ISS, return to crewed and robotic lunar exploration to test technology that would facilitate expeditions to Mars and develop a Crew Exploration Vehicle for transport, later named Orion.

Constellation contracts were awarded in 2006, most notably to Boeing and Lockheed Martin—legacy aerospace companies that worked almost entirely in the government market. The plan was to use two different launch vehicles for different purposes, the Ares I for transporting crew to orbit, and the heavy-lift Ares V rocket, with deep space potential, for cargo. After several years, in 2009, the Augustine Commission was tasked with reviewing Constellation and, if needed, providing prospective alternatives. The final report stated that the "current U.S. human spaceflight program appears to be on an unsustainable trajectory" (Review of U.S. Human Spaceflight Plans Committee, 2009, p. 19). It cited discrepancies between mission objectives and the resources available to make them a reality. Constellation's timeline was delayed significantly—Ares I and Orion were not prepared to launch to the ISS until 2016, which was past the point when the ISS was billed to be deorbited.

The Augustine Commission put forth an Ares V Lite dual launch variant aimed at consolidating costs. As evidenced by Shuttle, government-funded rockets launch infrequently at too great a share of NASA's annual budget. For the price of launches to go down, the rate of launches must go up. The involvement of the burgeoning commercial space industry, the document claims, has the potential to ameliorate this problem: "If we craft a space architecture to provide opportunities to industry, creating an assured initial market, there is the potential—not without risk—that the eventual costs to the government could be reduced substantially" (Review of U.S. Human Spaceflight Plans Committee, 2009, p. 20). The commission recommended creating incentives for commercial services to deliver crew and cargo to orbit for two reasons. One, so that industry competition would readily lower costs, and two, so that a government entity in NASA would not be directly competing with a capable private sector.

In the FY2011 Budget Release in 2010, President Barack Obama canceled the Constellation program, added $6B to NASA's budget over a five-year term, and allocated $3.1B to research and development for a future heavy-lift launch system. New funding was also made available for Earth Sciences and several advanced technology programs. The Obama White

House directed NASA to build partnerships with commercial entities to provide the primary service of transporting crew to the ISS—of which the operational schedule had just been extended due to the reallocation of funds (OSTP & NASA, 2010, p. 2). This initiative went on to become Commercial Crew, a program which materialized in large part due to Lori Garver's effort. Garver led the NASA transition team for Obama, who later nominated her as Deputy Administrator of the agency, a position she held from 2009 to 2013. In her memoir *Escaping Gravity* (2022), Garver explains that folding Constellation, and terminating contracts worth billions generated tremendous bipartisan backlash on the Hill. The reaction, she writes, was caused by parochialism and the disruption of a long-lasting arrangement:

> Entrenched aerospace interests had spent their careers designing versions of Constellation-like programs to keep expensive infrastructure and jobs in key congressional districts at the expense of more competitive programs, regardless of operational effectiveness. (Garver, 2022, p. 26)

Congressional delegations in states that housed industry giants acted in their constituents' interests. With the power of the purse, they were able to create a system wherein large-scale, long-term rocket programs funded thousands of jobs in perpetuity.

Big Aerospace holds up the other half of this structure. It is composed of the legacy Apollo contractors—Boeing, Lockheed Martin, and Northrop Grumman—that are the top three suppliers for the U.S. Department of Defence and the corporate pillars of the military-industrial complex (Berger, 2022b). Back in 2006, when Constellation was taking shape, Boeing and Lockheed Martin joined into an equal partnership to form the United Launch Alliance (ULA), consolidating the expendable Atlas V and Delta IV Heavy rocket families (Mann, 2020). The joint venture held a sanctioned monopoly on Pentagon launch contracts for the next decade (Davenport, 2018, p. 206). Most of NASA's business with these legacy companies makes use of a cost-plus contract model, meaning that, in a given project, all expenses are paid for by the customer including additional funds for novel or unexpected challenges. Profit is thus guaranteed for the contractors, and there becomes little incentive to curb cost overruns or to complete projects early, or even on time (ergo, Constellation). This mechanism of the industry is "either a product of a broken system that curries favor to wealthy industries or an example of representative democracy working as it should [...] Perhaps it's a bit of both" (Dreier, 2022). To both sides, maintenance of the status quo is of mutual benefit. Former NASA Administrator Dan Goldin referred to the traditional aerospace industry's pact with involved government figures as the self-licking ice cream cone—a system whose sole purpose is to sustain itself indefinitely (Garver, 2022, p. 62). As it turns out, this system is exceedingly effective at doing so.

In the NASA Authorization Act of 2010, Senate declared it U.S. policy for NASA to develop a "Space Launch System" and a multi-purpose crew vehicle by the end of 2016. The legislature, led by Senator Kay Bailey Hutchison from Texas and Senator Bill Nelson of Florida, required the agency to "utilize existing contracts, investments, workforce, industrial base, and capabilities from the space shuttle and Orion and Ares 1 projects" (National Aeronautics and Space Administration Authorization Act, 2010). Extant Constellation partnerships were leveraged to construct a heavy-lift rocket and spacecraft using Shuttle-derived hardware, maintaining Big Aerospace's specialized workforce. Terminating any contract necessary for the transition to Orion or SLS was prohibited. The Act effectively repackaged the Constellation program and ensured that the expenditure of heavy-lift rockets would continue to fall upon the tax-payer at the benefit of legacy contractors and their local economies. Critics disparagingly refer to SLS as the *Senate* Launch System. "Thousands of people would spend their next decade working on systems that weren't sustainable over the long term," Garver writes, "I felt like I'd failed the workforce and the country" (2022, p. 133). Over a decade later, Senator Nelson is now NASA Administrator Nelson, and the 2010 Authorization Act's heavy-lift launch vehicle has materialized with the first operational mission of SLS, Artemis I.

Figure 4

Early Morning Artemis I

Note. SLS rocket and Orion spacecraft at Launch Pad 39B during cryogenic propellant loading.

Using figures from the 2021 NASA OIG audit, the major Artemis cost-plus contracts follow. Lockheed Martin is the sole source contractor of the Orion Multi-Purpose Crew Vehicle. The contract for Orion, signed for the Constellation program, was worth \$3.9B at the time, but has since grown to \$13.8B. The company was also awarded a \$2.7B contract for 6 additional capsules. Boeing, the primary SLS contractor, will produce the Core stages and Exploration Upper stages, respectively. United Launch Alliance is providing the Interim Cryogenic Propulsion Stages based on the Delta Cryogenic Second Stage used for the Delta IV rockets. Aerojet Rocketdyne was awarded one contract to adapt 16 RS-25 engines from Shuttle, and a second to restart production for 24 more, for a combined \$4.2B. That means \$140M per unit for engines initially designed for reuse in the 1970s, that are now expended every mission. Northrop Grumman is tasked with manufacturing 35 solid rocket booster segments based on left-over Shuttle technology for $4.3B. The aggregate value of SLS's six major contracts is $20.4B. NASA commissioned Bechtel to construct the second Mobile Launcher for the Exploration Ground systems for $383M in 2019. ML-2 is a ground structure that will be used to launch the larger and more powerful SLS variants, Block 1B and Block 2. A 2022 NASA OIG audit of Bechtel projected that ML-2 will not meet the Artemis IV deadline and that its cost will have ballooned to approximately $1B (p. 10). Nearly every assessment of Artemis hardware shows that costs have reliably increased and deadlines have inevitably slipped—inherent (mal)functions of the cost-plus contract model.

From its inception to today, Artemis has worked with over a thousand industry partners and suppliers in all fifty states and Puerto Rico, forming a parochial agenda in almost every congressional district (Dreier, 2022). America's legacy space economy is underpinned by a nation-wide bipartisan political coalition that will be extremely difficult to undo anytime soon. Despite being years behind schedule and billions over budget, every fiscal year of the program's progression, from 2012 to 2022, Congress appropriated more funds for SLS/Orion than NASA requested (Minter, 2022). It may not be unfair to think of the rocket as Frankenstein's monster of costly "heritage" hardware ensnared in bureaucratic affairs—or to think of the continued development of SLS rockets at exorbitant costs as the root cause for going back to the Moon, not the other way around. Nevertheless, SLS has been heavily modified and upgraded with modern technology, assembled into the most powerful launch system ever created on the night SLS first took to the sky (Cokinos, 2022). For now, there are no operational commercial alternatives with SLS's capability to send both crew and cargo to the Moon (NASA, 2021). NASA's return to crewed lunar exploration is an incredible accomplishment of engineering, even though, so shallow under the surface, it is evident that the Artemis program's earliest phases are a political means to an industrial end.

Billionaire Entrepreneurs in the Era of Privatization

Over the past two decades, private companies with contemporary business philosophies, sometimes referred to as "NewSpace," have forced their way into the space economy's previously closed circuit. These companies' technological innovation has upset the aerospace status quo, forming a new epoch in human spaceflight—the commercial space age. Traditional holders of power still do so, but with every launch of a civilian, commercial, or military payload on a launch vehicle developed by the private sector, the self-licking ice cream cone starts to melt. What system might take its place? For now, that is up in the air. One thing is certain, as the rate of launch increases in frequency, with multiple entities developing novel and competitive systems, the relative price of launch decreases. The motivation to provide space hardware and infrastructure centers on two economically lucrative near-Earth opportunities: orbital launch and transportation services and space tourism. In other words, private companies secure contracts to send humans to the atmosphere's edge or to deliver payloads to low Earth or geostationary orbit at aggressive pricing. In effect, this makes the cost-per-launch more accessible to corporate and government customers, readily opening the market of outer space.

More often than not, NewSpace ventures adopt a vertically integrated business model, meaning that resources typically spread across multiple supply chains are consolidated, allowing for more control over the efficiency and cost of manufacturing hardware. Profit margins can be improved, but the companies take on considerably more risk. Research, engineering, testing, and manufacturing of spacecraft from scratch is by no means an inexpensive venture and rockets are not completed without explosions and remodeling along the way. It is unsurprising then that these enterprises are owned by some of the wealthiest individuals in recorded history. In the classical space age, crewed space exploration was something done by government agencies with government funds. Earth orbit is no longer exclusively bound to spacefaring nation states. Billionaires with ambitious near and long-term visions of outer space have entered the fray, founding and financing rocket companies that are now major industry players. Of the growing number of entrepreneurs in the modern era, there are two individuals that hold the largest stake in the fledgling commercial space economy with the development of fully-reusable, human-rated launch systems and spacecraft—Elon Musk and Jeff Bezos.

Back in 2000, Bezos founded Blue Operations LLC, what would become Blue Origin—a space company named after Earth. Bezos accumulated wealth as the founder and CEO of e-commerce company Amazon.com, Inc. What was an online bookstore originally is now one the world's largest companies by market cap and the internet's biggest retailer. In the late nineties, around the same time that Bezos began offering consumer goods other than books on Amazon.com, Musk co-founded an online bank called X.com which, through a merger, became the online payment service PayPal. In 2002, e-commerce auction site eBay acquired PayPal for $1.5B and Musk, the largest shareholder, profited $180M (Vance, 2017, p. 64). Musk put $70M of the capital towards electric vehicle manufacturer Tesla, Inc. and used $100M to start up Space Exploration Technologies Corp., better known as SpaceX. The trajectory of the launch industry was profoundly changed—most just didn't know it yet.

Bezos and Musk have each held the title of the world's richest person. Throughout 2021, Bezos' wealth hovered around $200B. By the year's end, Musk surpassed Bezos through a round of SpaceX investor funding (Carpenter, 2021). In an email to Forbes accepting the accolade, Musk characteristically wrote that he was "sending a giant statue of the digit '2' to Jeffrey B., along with a silver medal" (Cai, 2021). Both fortunes were amassed by holding an ownership stake in companies which saw a meteoric rise in value—Bezos owning 10% of Amazon and Musk owning 13% of Tesla. As the market fluctuates, so does their net worth. Most importantly, shares are *unrealized assets*, not taxable until they are cashed out. Even as individual wealth may accrue into the hundreds of billions, Bezos and Musk do not pay tax on those gains. In 2007 and 2011, as the wealthiest person on the planet, Bezos paid zero dollars in federal income taxes—Musk did the same in 2018 (Eisinger et al., 2021).

It is no mystery that wealthy people play by different rules. Still, a better picture of the ultra-rich's financial reality was revealed when, in 2021, a classified dossier of financial information about America's wealthiest people was leaked. ProPublica used the Internal Revenue Service data cache to compare the amount paid in taxes to the estimated growth in individual wealth, a metric they dubbed the "true tax rate." For the fiscal years of 2014 to 2018, Musk's wealth grew $13.8B as he reported his total income at $1.52B, paying $455M in taxes. That means Musk paid 3.27% of his net worth in taxes (Eisinger et al., 2021). In the same time frame, Bezos' wealth grew $99B but reported $4.22B in income and paid $973M in taxes, putting his true tax rate at just 0.98% (Eisinger et al., 2021). It is a legal loophole of the American tax system: if one can avoid *making* an income, one can avoid paying taxes. Musk does not take up $1 pay from Tesla and SpaceX as an act of generosity to everyone else on the payroll, it is part of a tried-and-true technique of tax avoidance. Instead of a salary, the super-wealthy take out loans (not taxed) and use their stocks (also not taxed) as collateral. Bezos earned a consistent base salary of $81,840, the same figure from 1998 until 2021 when he stepped down as Amazon CEO (Knorr-Evans, 2021). The decision was made, as Bezos penned in an email to Amazon employees, to spend more time on his philanthropy initiatives and other ventures such as Blue Origin (Amazon, 2021).

The mechanisms of systemic and ever-growing wealth disparity are largely how SpaceX and Blue Origin had the capital to break into the traditionally insular space economy in the first place. Today, the two companies' financial situations are very different. For Blue Origin, the formula is simple, and Bezos speaks to it candidly:

> The only way that I can see to deploy this much financial resource is by converting my Amazon winnings into space travel. That is basically it. Blue Origin is expensive enough to be able to use that fortune. I am liquidating about $1 billion a year of Amazon stock to fund Blue Origin. And I plan to continue to do that for a long time. (Döpfner, 2018)

This is Blue Origin's unabridged business model. Each year, Bezos draws a lump sum from his corporate "winnings" and puts it into his outer space passion project. Likewise, Musk sold millions of his Tesla shares worth billions of dollars to fund his late-2022 takeover of the social network company Twitter, Inc. By contrast, SpaceX has become a profitable business venture, having benefited from NASA and military contracts at critical junctures and is currently dominating the international commercial launch market. Unlike Blue Origin, SpaceX's day-to-day operations are sustained without heavy reliance on internal investment. Rather than paying an equitable share of their net wealth to society (relative to the tax contribution of the average American household), the two centi-billionaires have used their vast resources to build space companies from the ground up and to privately fund rockets that have fundamentally altered the space economy. A running joke in the space community goes like this: How does one become a millionaire in space? Start as a billionaire (Beames, 2021).

It should be noted that the first privately funded vehicle for human spaceflight took to the sky having little to nothing to do with Musk or Bezos. SpaceShipOne was developed in 2003 by Mojave Aerospace Ventures, designed by aerospace engineer Burt Rutan's company Scaled Composites and financed by an entirely different billionaire of the tech industry, Paul Allen, the co-founder and former CEO of Microsoft. Rather than blasting off from the ground, the rocket-powered SpaceShipOne was tethered to the belly of its "mothership" carrier WhiteKnightOne and air-launched at an altitude of 50,000 feet (Rutan, 2020). SpaceShipOne does not travel at a speed required to achieve orbital velocity, meaning its spaceflights are suborbital. Nonetheless, the vehicle and its passengers experience a few minutes of weightlessness at apogee, the highest point of the rocket's trajectory, before gliding back to Earth. The unusual "feathered" wing spacecraft was developed as an entrant to the Ansari XPRIZE competition in 1996. XPRIZE pledged $10M to the creators of the first crewed spacecraft backed by a non-government organization to cross the Kármán line—the boundary between the planet's atmosphere and outer space—twice within two weeks. The foundation's website notes that the contest intended "to lower the risk and cost of going to space" by offering a financial incentive for the creation of reliable and reusable spacecraft "that finally made private space travel commercially viable" (XPRIZE, n.d.).

Near the end of 2004, SpaceShipOne passed the 100-kilometre threshold in dual suborbital flights, and Mojave Aerospace Ventures claimed the Ansari XPRIZE. Days before, Sir Richard Branson, the billionaire co-founder of the Virgin Group, announced that his newly formed space company Virgin Galactic had purchased the rights to licence the SpaceShipOne technology. Company logos were painted on the spacecraft just before the contest-winning launches (Davenport, 2018, p. 97). Branson commissioned Rutan to design a second generation of the spaceliner to bring paying customers to the edge of space: SpaceShipTwo. However, the program suffered a catastrophic setback in 2014 when the feathering system of *VSS Enterprise* deployed too early during a test flight, causing an in-flight breakup and the death of co-pilot Michael Alsbury (Adler, 2021a). It was the first spaceflight casualty since *Columbia*. After several years of investigation and modifications made to the feather-locking system, in 2021, the second SpaceShipTwo vehicle *VSS Unity* performed a successful test flight with four passengers, including Branson, making him the first billionaire to enter space using his own spacecraft (Knapp, 2021). An asterisk to some, this flight did not pass the Kármán line. SpaceShipTwo was delayed with upgrades for years but has since restarted commercial spaceline operations, launching tourists at $450,000 a seat (Virgin Galactic, 2023).

Nine days after Branson became a commercial astronaut aboard *VSS Unity*, Blue Origin's New Shepard rocket *RSS First Step* carried four passengers to suborbital space, including the company's owner, Jeff Bezos. This made Bezos the second billionaire to launch in a vehicle for which he had footed the bill. New Shepard's second passenger was Jeff's brother, Mark Bezos. Also onboard *RSS First Step* was 18-year-old Oliver Daemen—the company's first paying customer—and 82-year-old aviator Wally Funk. At the time, the duo became the youngest and oldest astronauts, respectively (Bilton, 2021). Scheduled 52 years after the Apollo 11 Moon landing, the *NS-16* mission was Blue Origin's first crewed flight after 15 uncrewed test flights. At the post-flight press conference, Bezos thanked "every Amazon employee and every Amazon customer, because you guys paid for all this" (Gohd, 2021). The flourishing e-commerce market sent Bezos to the edge of space, and he knew it.

Virgin Galactic may not have explicitly pushed up its launch date so Branson could wrest the accolade away from Bezos in the suborbital billionaire space race, but it certainly appears that way. Regardless of the launch order or the elevation reached, both companies sent their owners on inaugural crewed spaceflights to publicize the debut of their launch vehicle and services to the suborbital tourism market. Blue Origin and Virgin Galactic's services are similar, with passengers experiencing three to four minutes of weightlessness. However, the vehicle architecture is fundamentally different. New Shepard is a single-stage rocket comprising a pressurized crew capsule and a booster rocket. Both components are fully reusable, with the booster performing a vertical take-off and landing. Between these two points, the crew capsule separates from the rocket, and coasts through space 100 kilometres above the Earth's surface before reentering the atmosphere and landing under parachutes. The entire flight takes about eleven minutes. Unlike the piloted SpaceShipTwo, New Shepard is a completely automated system from launch to landing.

Blue Origin's approach to the launch industry has been to make gradual but incremental improvements, captured by the company's motto *gradatim ferociter* (step by step, ferociously). The company is known for telegraphing the naming scheme of its rockets. An early developmental vehicle was named Goddard after American rocketry pioneer Robert Goddard. Essentially, it was a proof-of-concept prototype rocket that launched upwards several hundred feet and then returned to the launch pad to demonstrate competence in vertical landing (Adler, 2021b). Goddard evolved into the New Shepard system, named after Mercury-era astronaut Alan Shepard, the first American to enter space on a suborbital flight. With each successful landing of New Shepard, a stencil of a turtle is painted onto the spacecraft's hatch, alluding to Aesop's fable "The Tortoise and the Hare." In his telling of the rise of NewSpace in *The Space Barons* (2018), Christian Davenport explains that the symbol is an effectual embodiment of the company as a whole (p. 152). Blue Origin works slowly but methodically in the West Texas desert, hitting milestones while hidden out of sight, like a tortoise in its shell. Thirty-two people have since crewed New Shepard in six suborbital flights. Known for its furtiveness, Blue Origin has yet to disclose the official price of a ticket. The mascot is an apt one. For all of New Shepard's suborbital achievements, the human-rated, fully reusable launch vehicle is a technological stepping stone for something much, much larger.

Blue Origin publicly announced their next-generation, heavy-lift orbital launch vehicle New Glenn in 2016. The rocket is named after the first American astronaut to orbit the Earth, John Glenn. At 322 feet tall, fully stacked, New Glenn outsizes the 59-foot New Shepard by a considerable margin. The entire suborbital rocket would fit inside the massive payload bay of its successor (Blue Origin, 2019), or as Bezos referred to it, the "Very Big Brother" (Victor, 2016). New Glenn's first stage is designed to be reused up to 25 times, landing vertically like New Shepard. The initial recovery plan was to land on a converted cargo ship as it was underway, but the idea and the ship have since been scrapped (Mooney, 2022). In addition to the New Glenn system, Blue Origin's BE-4 engines have also been commissioned for United Launch Alliance's next-generation heavy-lift rocket, Vulcan Centar. Despite setbacks in manufacturing and testing, Blue Origin has delivered the BE-4's that will power Vulcan's first launch in 2023 and will carry Astrobotic Technology's *Peregrine* lunar lander (Boyle, 2022) *Peregrine* is one of several robotic missions in Artemis' Commercial Lunar Payload Systems (CLPS) program.

By 2018, the U.S. Air Force had committed $500M to Blue Origin through a Launch Service Agreement in a six-year public-private partnership as part of the National Security Space Launch (NSSL) program. The purpose of NSSL is to stimulate the development of launch infrastructure and viable rocket systems, both expendable and reusable, that could compete for future military contracts—rather than needing to rely on Russian parts, such as the RD-180 rocket engines used on ULA's Atlas V (Adler, 2021b). New Glenn had received $255.5M before the plug was pulled on Blue Origin and Northup Grumman's OmegaA rocket in 2020 when the newly minted Space Force instead opted for ULA and SpaceX as exclusive national security launch providers (Erwin, 2021). Having not been selected cost Blue Origin billions in expected revenue. As a result, New Glenn was "re-baselined" (Foust & Erwin, 2021). The quarter billion tax-payer dollars was significant in the rocket's development, but relatively modest compared to Bezos' original investment of $2.5B (Patel, 2017). With a gradually slipping timeline for its maiden flight, New Glenn is positioned towards the civil and commercial sector, aiming to compete with industry leader SpaceX in the payload rideshare market.

At this time, after more than twenty years of consistent private investment, Blue Origin has yet to go orbital. However, to realize his space infrastructure ambitions, Bezos says he is "willing to be patient for decades" (Levy, 2018). His pockets are assuredly deep enough to do so. "Our first orbital vehicle will not be our last, and it will be the smallest orbital vehicle we will ever build," Bezos wrote of New Glenn, "up next on our drawing board: New Armstrong. But that's a story for the future" (Davenport, 2016). New Armstrong would be named after Neil Armstrong, the first American astronaut to step foot on the Moon. If Jeff Bezos' Blue Origin is the tortoise that takes one slow and incremental step after the other, one could hazard a guess at whom, having leaped off the starting line, the hare might be.

Commercial Crew: Space Exploration Technologies, Corp.

2022 saw the most rockets sent into space in a calendar year at 180 launches, overtaking the previous record set in 2021 (Witze, 2023a). SpaceX's Falcon rocket family made up 61 of those launches with zero failures. That is, on average, one launch every six days of the year, an unprecedented cadence for a commercial entity. The People's Republic of China conducted 64 launches, two of which failed to make orbit. That puts the country with the second most active space program after the U.S. only one successful orbital launch ahead of SpaceX. "92% of missions completed with flight-proven first stage rocket boosters" the company tweeted at the year's end, "Falcon 9 now holds the world record for most launches of a single vehicle type in a single year" (SpaceX, 2022). Falcon 9 is SpaceX's workhorse, a two-stage reusable rocket powered by nine Merlin engines. Of the rocket's 60 launches in 2022, only four utilized new first-stage hardware. SpaceX delivered satellites to low Earth and geostationary transfer orbit for international communications companies such as Intelsat, Eutelsat, and OneWeb. There were also three crewed missions to the ISS. At 32 launches, over half of Falcon 9's flights were dedicated to deploying SpaceX's in-house satellite constellation, Starlink.

The remaining flight of SpaceX's banner year was a single launch of the Falcon Heavy for the U.S. Space Force's NSSL program. Falcon Heavy is composed of three modified Falcon 9 boosters strapped together, the combined 27 Merlin engines generating more than 5 million pounds of thrust at liftoff (Barnett & Wattles, 2018). It was the most powerful rocket in operation before Artemis I, when SLS leaped off the pad. USSF-44 used three brand-new first stages to loft six payloads into near-geosynchronous orbits, requiring the core booster to be expended (Dinner, 2022b). For Dr. Walter Lauderdale, the Space Systems Command's chief and USSF-44 mission director, successfully deploying unique payloads from multiple military and commercial partners was a “sign of what’s to come” (Sodders, 2022). The two Falcon Heavy side boosters, which performed synchronized landings, have already since been reused for another successful Space Force mission, USSF-67. 2022 was an extremely busy year for SpaceX, the busiest any launch provider has ever had. Before the year was out, Musk tweeted confirmation that the company would hasten the launch rate further in 2023, targeting 100 orbital flights (Musk, 2022).

SpaceX was not always recognized by its successes. In the early days, as detailed by Eric Berger in *Liftoff* (2021), the company was better known to the aerospace industry by its failures—specifically, its first orbital launch vehicle, Falcon 1. The expendable two-stage, small-lift rocket launched five times between 2006 and 2009 from Omelek Island of the Kwajalein Atoll in the Marshall Islands. Only two, the fourth and fifth, made it to low Earth orbit. Falcon 1’s inaugural launch ended less than a minute into the flight with the rocket pitching over and crashing into a coral reef (Berger, 2021, p. 79). With around $25M in launch contracts from awaiting customers and a $100M personal investment from Musk sunk into the project, the explosive misstep—and the two following missteps—was not an ideal introduction to the business (Berger, 2021, p. 99).

Even so, later that same year in 2006, NASA selected SpaceX for Commercial Orbital Transportation Services (COTS). This program incentivised the private sector to competitively develop systems capable of delivering commercial cargo and crew to the ISS (NASA, 2006). The COTS model was unusual for NASA, who nearly exclusively worked with Big Aerospace, but was significant as the agency sought viable replacements for Shuttle in the wake of the *Columbia* disaster (Garver, 2022, p. 184). Typically with cost-plus contracts, NASA has much control over the design, closely oversees the production, and ultimately owns the rights to the hardware. Using fixed-price, milestone-based payments, companies are expected to share in development costs and can commercialize the launch vehicles and spacecraft produced. SpaceX was awarded $278M in the original agreement and amendment funds later brought the total to $396M (Hackler, 2014, p. 58). NASA’s financial backing accelerated the production of an orbital spacecraft called Dragon and a serious scaling-up of the Falcon system: rather than Falcon 1’s single Merlin engine, the heavy-lift rocket had nine.

Bankruptcy loomed over both SpaceX and Tesla during the 2008 economic recession. Following the third launch failure in August, SpaceX cobbled together available parts from the Falcon 1 and successfully delivered the rocket’s second stage with an aluminum payload simulator, dubbed RatSat, to orbit (Berger, 2021, p. 175). By December, in the negotiations of SpaceX’s Gwynne Shotwell with then NASA Administrator Mike Griffin, SpaceX won a $1.6B contract with the Commercial Resupply Services (CRS) program for twelve flights of Cargo Dragon to the ISS. The award effectively saved the company from dire financial straits. Shortly thereafter, Shotwell was promoted to president of the company. Being paid to produce Falcon 9s and Dragon capsules at a high rate paired well with SpaceX’s move-fast-and-break-things workplace ethos. Falcon 9 began launching frequently, disasters becoming fewer and farther between, and prototype testing for the next technological leap began: vertical takeoff and landing. Booster landings on barges in the ocean, called autonomous spaceport drone ships, is now routine recovery procedure. With the Dragon C2+ launch in 2012, Dragon became the first commercial spacecraft to rendezvous with the ISS. The first quarter of 2023 saw SpaceX fly its twenty-seventh cargo resupply mission to the ISS, CRS-27. RatSat still orbits the Earth.

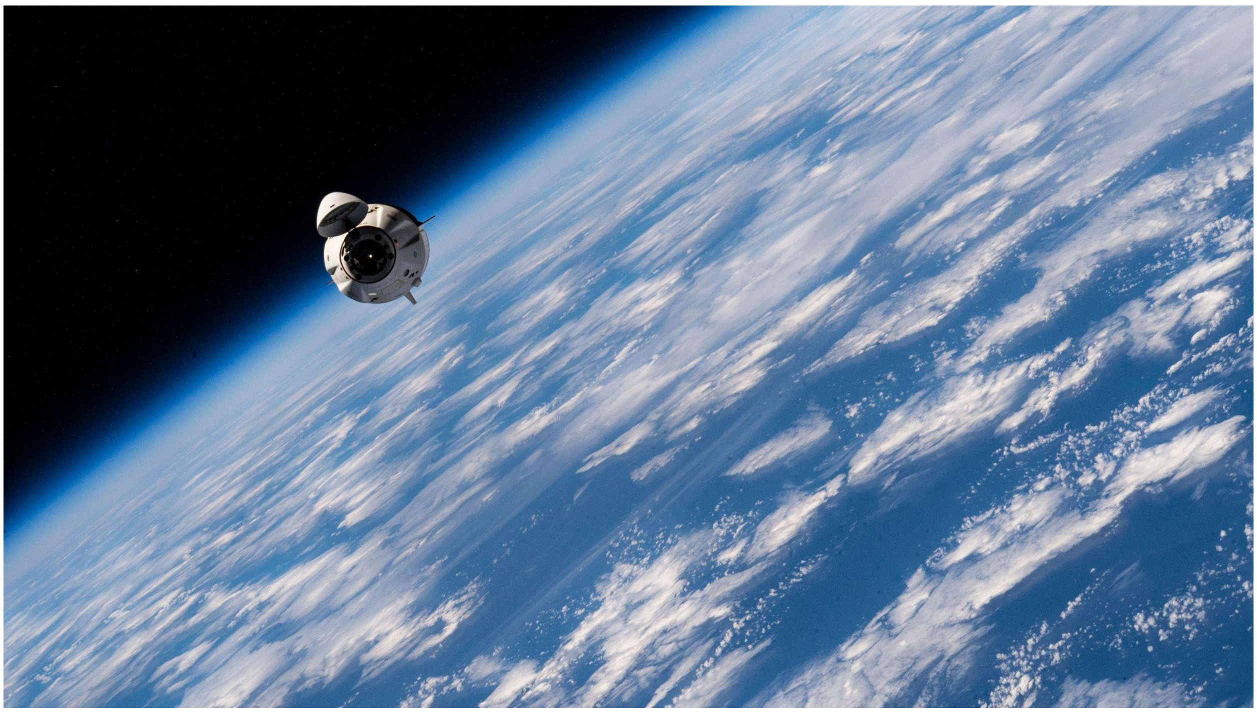
In 2014, SpaceX filed a lawsuit against the U.S. government. The company claimed that the multi-billion-dollar sole-source contract awarded to ULA by the Department of Defence (DoD) for 36 national security launches—in addition to an annual cost-plus “launch readiness” payment of $1B regardless of how many rockets were launched—was non-competitive (Berger, 2017). Musk repeatedly voiced criticism of the Alliance for its use of Russian-made engines on Delta and Atlas variants, which risked violating international sanctions during Russia’s invasion and annexation of Crimea (Davenport & Fung, 2014). By offering a launch price of under $100M and standing to make little profit, SpaceX severely undercut ULA, whose cost-per-launch was in the $200M to $300M range and rising (Ward, 2019, p. 54). In the end, Musk had ruffled enough feathers for the DoD to open national security missions to a bidding process (which shaped the NSSL program) and Falcon 9 was certified for military contracts. A decade-long industry monopoly had been broken. ULA would enter a partnership with Blue Origin to supply BE-4 engines, built on American soil, for the next-generation Vulcan Centaur.

Soyuz spacecraft launched from Kazakhstan’s Baikonur Cosmodrome were the only means to transport people back to the ISS after the discontinuation of Shuttle. That is, until 2020, when SpaceX’s Falcon 9 sent NASA astronauts Douglas Hurley and Robert Behnken to the ISS for the Crew Dragon Demo 2 mission (Oberhaus, 2020). In a palpable display of government-private partnership, Demo 2’s crew were driven to the launch pad in Tesla Model Xs. The mission was the first crewed orbital spaceflight launched from America since 2011 and the culmination of a series of open competitions in an umbrella program called Commercial Crew. The program was made to develop cost-effective and reliable modes of transport to the ISS sourced from the commercial sector, ending NASA’s reliance on Russian launch systems whilst having a tenuous geopolitical relationship. After sanctions were imposed on Russia in 2014, then deputy prime minister Dmitry Rogozin suggested the U.S. “bring their astronauts to the International Space Station using a trampoline” (Heilweil, 2022). Boeing, Blue Origin, Sierra Nevada, and SpaceX received awards for their successful bids in the initial two Development of the Commercial Crew (CCDev) rounds. The third round, Commercial Crew integrated Capability (CCiCap), saw NASA allocate $440M to SpaceX and $460M to Boeing for their space capsule designs while Sierra Nevada Corporation received $212.5M to develop their spaceplane, Dream Chaser (Malik, 2012). Blue Origin did not compete in CCiCap, opting for private investment.

In the final phase of CCDev, Commercial Crew Transportation Capability (CCtCap) contracts were awarded to SpaceX ($2.6B) and Boeing ($4.2B) for Crew Dragon and Crew Space Transportation-100 Starliner; two fully funded, redundant transport systems (Wall, 2014). A 2019 OIG report calculated the average cost per seat to be $90M for Boeing and $55M for SpaceX, whereas NASA paid Roscosmos (the Russian space agency) an average cost per seat of $55.4M on Soyuz between 2006 and 2020 (p. 4). Both Commercial Crew spacecraft have experienced technical difficulties in uncrewed tests; Crew Dragon exploded in a grounded engine abort test and an offset clock caused an untimely thruster burn, sending Starliner to the wrong orbit (Chang, 2019). SpaceX has completed six operational Commercial Crew missions which docked to the ISS for crew rotation. After several years of delays, Boeing has yet to certify Starliner for human-rating (Foust, 2023a). Open competition and fixed-price, milestone-based awards in Commercial Crew demonstrated to NASA that NewSpace can out-perform Big Aerospace—sending astronauts to orbit and back in less time, more frequently, and at a lower price point. Ever the Aesop's hare, SpaceX has outpaced its competition, but the company has not yet shown signs of slowing down.

Figure 5

Crew-2 Return Mission



Note. Crew Dragon *Endeavour* approaches the ISS for docking.

The switch from in-house production to out-sourcing with Commercial Crew represented a meaningful course correction for NASA. The ardent need to supply the ISS with cargo and crew obliged NASA to turn to Russia and the commercial sector as Constellation's Ares rockets were proving too great an investment of time and funds. Right as tech-industry entrepreneurs were taking their start-ups and prototypes off the ground, an opening was made for the private sector to wedge itself into the space industry. Where Blue Origin aligned itself with the old guard, SpaceX faced it head-on. SpaceX has been able to leverage batches of NASA funding to expedite the production of their next launch system and spacecraft, each time bigger than the last. Alongside the Starlink satellite megaconstellation, the current vehicle project is the company's most ambitious. It required SpaceX to lay off 10% of its roughly six-thousand-person staff. The company stated that to "succeed in developing interplanetary spacecraft and a global space-based internet, SpaceX must become a leaner company" (Masunaga, 2019). Throughout its developmental lineage, the vehicle was known as the Mars Colonial Transporter, the

Interplanetary Transport System, and the Big Falcon Rocket. Musk seems to have settled on a name for the rocket intended to bring humans to the red planet: Starship.

Composed of the Starship spacecraft (second stage) and Super Heavy booster (first stage), the Starship system is poised to be the largest and most powerful launch system ever created. Super Heavy's 33 Raptor engines exert 16.5 million pounds of thrust, capable of delivering 150 metric tons of payload to low Earth orbit (Dvorsky, 2023). The unmatched potential payload capacity creates avenues for space infrastructure that were previously not possible. Use of Starship for a private mission called dearMoon, planned in 2023, has been purchased by Japanese billionaire Yusaku Maezawa for a lunar flyby with a crew of eight international artists (Howell, 2022). Until Starship completes an orbital launch, there is no commercial equivalent to the power of the SLS with 8.8 million pounds of thrust (NASA, 2021). However, if the rocket can perform the numbers SpaceX estimates, then any variation of SLS will not hold a candle to Starship. The lasting remnants of legacy aerospace with SLS/Orion through hardware and policy may give the impression that the Artemis program functions in opposition to NewSpace actors, like SpaceX. A variant of the Starship system is, in fact, Artemis' ticket to bring astronauts back to the Moon.

The American spacecraft manufacturing and launch service industries have been ceded to commercial entities. Advantageous outcomes in recent partnerships, such as Commercial Crew, have provided a "template for how NASA will use commercial vehicle contractors to select, train and launch crew for the Artemis Lunar Program" (von Ehrenfried, 2020, p. 111). Positioned to turn a profit, commercial actors are instrumental in the very architecture of Artemis. SLS, coined "yesterday's rocket for yesterday's world," is a remnant of a parochial system that is quickly falling out of favour, perhaps for good reason (Robertson, 2023). Be that as it may, the political influence of Big Aerospace, forged during the Apollo era and part of the American military-industrial complex, cannot be understated. NASA finalized a $3.2B contract with Boeing to continue SLS manufacturing for as many as ten core stages and eight upper stages (NASA, 2022b). The rocket will likely launch at year-long intervals for decades; the self-licking ice cream cone will not go quietly into the night. Space is in a consequential period of transformation. The dynamisms of power between agencies, commercial entities, policymakers, and the ultra-wealthy are elastic and the future is as precarious as ever.

At present, SpaceX is head-and-shoulders above all competitors; playing catch-up is a near-impossible task at this point. However, in the launch business, things move fast. That is, if they are not delayed. Recent initiatives have affirmed that funnelling hundreds of millions to billions of tax-payer dollars to NewSpace companies (who are willing to split the bill) does seem to be a more *effective* system for human spaceflight. Whether handing over the reins to the start-ups of solar-system-minded billionaire entrepreneurs is a more *preferable* system is open to debate. Privatization of the space industry in the contemporary space age has and will continue to lower the monetary threshold of reaching orbit and creating business in outer space. But as those of us on Earth might ask, at what cost?

Chapter Three: Contextualizing the Planetary Future

The future is already here—it's just not evenly distributed.

— William Gibson

Exploration and Use of Outer Space

Before venturing out to other worlds, to permanently expand human habitat across the solar system or with an intent to come home, much is to be determined in near-Earth space. Low Earth orbit, or LEO, is the arena where we have the most practical expertise, with a continuous crewed presence aboard the ISS since 2000 and an exponentially growing industry for artificial satellites configured into so-called "megaconstellations." These space infrastructures are double-edged, offering scientific and environmental benefits that necessarily incur scientific and environmental risks. The features of near-Earth space exist only in relation to Earth and its celestial mechanics, so they are "actually *part of the planet Earth"* (Deudney, 2020, p. 80). Earth's terrestrial and atmospheric regions, while important to us as beings who survive in them, are only part of the planet's domain. Space is infinite in scope, but near-Earth space—from the Kármán line to low Earth orbit to geostationary orbit—is decidedly not. It is a shared environment subject to pollution and misuse. Humankind's technical extension into these geographies bears allowances and limitations, disclosing what our relationship with these outer spaces is and will be. Therefore, outward expansion requires a consideration of not only the economy but the *ecology* of our planet's near-Earth space, too (Nikoghosyan, 2017). Such changes in perspective open difficult dialogues about technological reach, social order over distance, and the geopolitical structures that enact said reach.

Economic historian Harold A. Innis wrote on patterned technological historiographies in *The Bias of Communication* (2008), published in 1951, a year before his death. The book elucidates connections between modes of communication and the culture and political economy of society. He found there to be civilizations with *space-biased* technology and the analog, civilizations in which technology *biases time*. The former is characterized by non-durable media of written tradition, such as papyrus, which could spread information quickly to obtain control over distance (Innis, 2008, p. 37). The latter by durable media such as stone or clay, which could not be easily moved nor widely consumed, effecting decentralization. Oral tradition typified time-biased societies, fostering an understanding of temporal continuity distinct from the written equivalent. Innis cited the mechanization of print media through the industrial printing press and the centralization of information through radio broadcast to contend that such technologies in (space-biased) cultures accentuated ephemerality (2008, p. 82). These methods of communication are of instantaneous and then swiftly fleeting importance. "With these powerful developments" Innis wrote, "time was destroyed and it became increasingly difficult to achieve continuity or to ask for a consideration of the future" (p. 83). A society or bureaucracy whose objective is to control swaths of space, Innis argued, loses touch with time itself.

The concept of space-time bias predates Earth's first artificial satellite *Sputnik I* in 1957 and the ensuing space age by about a five-year window. Innis' scholarly perspective of imperial culture in North America was developed during a post-War era in which he found society becoming inundated by instantaneous media forms. An undue obsession with the present, with the immediate moment, tipped the scales of politics and economics towards space, compelling

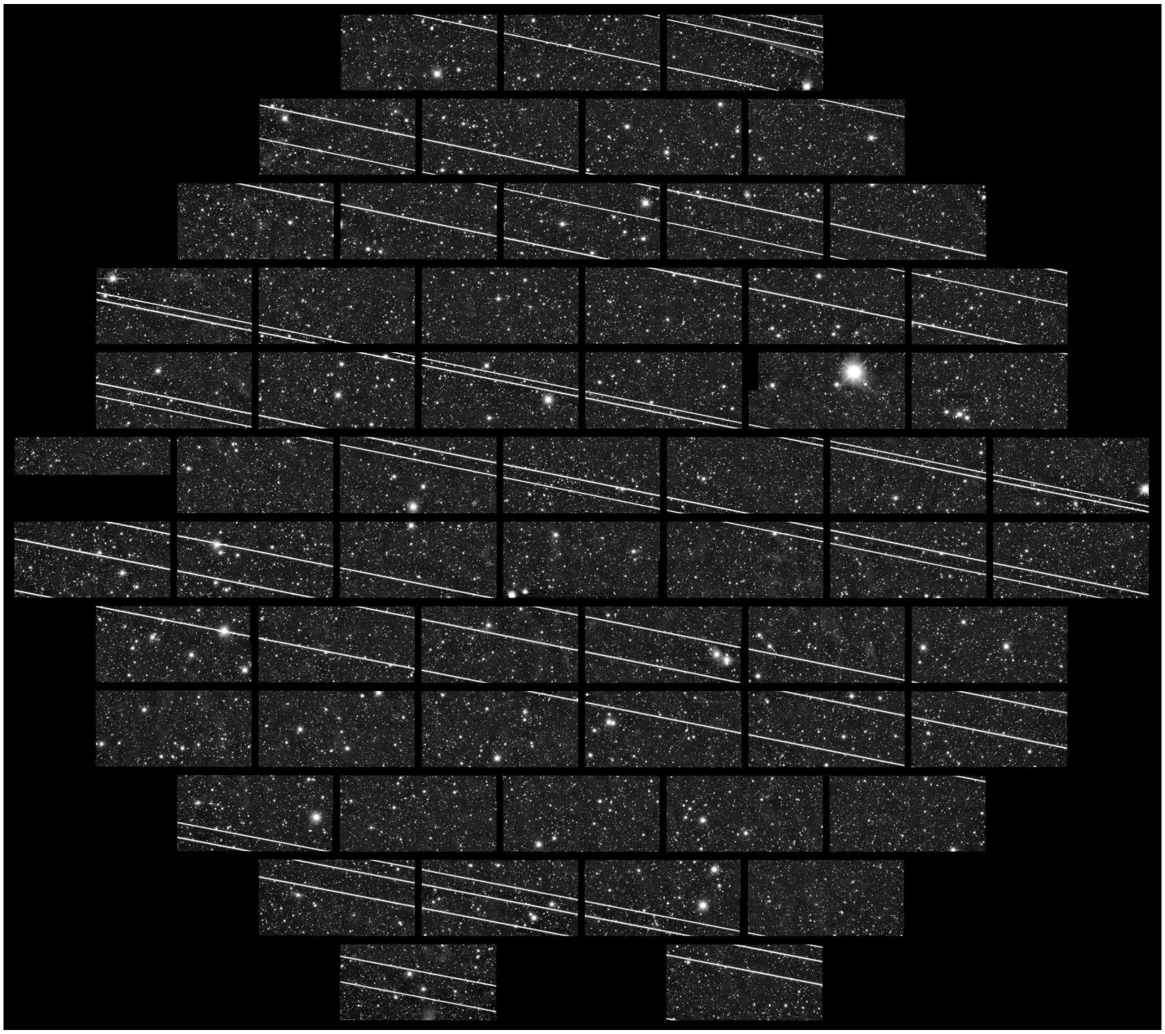
Innis to make “a plea for time” (2008, p. 61). The equilibrium of space and time in culture becomes imbalanced as a centralized state concentrates singularly on control of geography and demonstrates a willingness to intervene to maintain those geographies, industries, and monopolies of knowledge. To Innis, the crux of it all is communications. The growth and collapse of civilization are predicated on its interrelation with space and time, measured by and dependent on the infrastructures and mediums of its communication technologies.

In the approximately seventy years since *The Bias of Communication* and *Sputnik*, more than ten thousand satellites (and counting) have been launched into low Earth and geosynchronous orbit. Over eight thousand are still in space today, but roughly only half still function. The bulk of these are communications satellites that retransmit signals (television, radio, telephone) around the Earth’s curvature to relay information between geographical points at the speed of light. In the book *In the Meantime* (2014), media theorist Sarah Sharma writes that space-biased societies “spatialize time,” and in effect, time becomes “a resource, commodity, and sequence of events that can be managed and controlled. A technology that saves time, then, is in fact a spatially biased technology” (p. 12). Satellites are a space-biased infrastructure in which the immediacy of global data exchange causes the dissolution of time. Earth observation and imagery satellites are indispensable in the collection of climate data on oceans, clouds, wildfires, urban centers, agriculture, volcanoes, and the polar ice caps, but they are second to those for communication and not by a small margin. Technology that bridges the gaps of distance by making information travel at greater speeds is a more profitable enterprise than those considering longevity. The market share of communications satellites and their technological capability have risen in tandem—the industry sector was valued at more than $72B in 2022 and is projecting exponential growth (Ziegler, 2023). With many places in the world lacking reliable internet connectivity, there is no shortage of global bandwidth demand.

From the outside, constructing rockets is champion in the space economy, but “the money is in the satellites and data communication services,” states Ashlee Vance, citing Starlink as the majority source of the SpaceX’s valuation (Glick, 2023). Starlink is a satellite internet megaconstellation, or at least part of one. Today, there are over four thousand satellites in Starlink’s first generation operating in five orbital shells of LEO, and the company has regulatory approval to put up 12,000 more (Pultarova & Howell, 2022). Units have a roughly five-year lifespan before maneuvering to deorbit in the atmosphere. SpaceX is currently requesting permission from the Federal Communications Commission (FCC) to launch thirty thousand second-generation satellites, an order of magnitude above the number of objects *ever* sent to space (Sesnic, 2023). Moreover, Starlink is only one of several constellations in the works, with OneWeb, Amazon’s Project Kuiper, and China’s Guowang system all at various stages of development (Jones, 2023). According to astrophysicist Jonathan McDowell’s calculations, the total number of satellites planned for launch is well over 400,000 (2023). Low Earth orbit would become an “interstate highway, at rush hour in a snowstorm with everyone driving much too fast," McDowell analogizes, "except that there are multiple interstate highways crossing each other with no stoplights" (Pultarova, 2023). We are hurriedly moving towards global internet coverage—megaconstellations are an infrastructure befitting an interconnected civilization in the information age. Just as it happens on land or in water, the mechanisms of a highly lucrative industry in near-Earth space will incur effects on environments and people as regulation lags behind. This rapid innovation raises the necessary question: what are the consequences of an increasingly congested orbital environment?

Figure 6

iotw1946a



Note. Starlink satellites imaged shortly after launch by the Víctor M. Blanco 4-meter Telescope.

Starlink has already adversely affected the night sky. Still only at a fraction of its planned numbers, the constellation is proving to be disastrous for astronomy. Photographs from ground-based observatories and telescopes in LEO are increasingly marked by long streaks, as the reflection of the Sun's light on satellites trails across the image (Sudder, 2021). A paper by Sandor Kruk and colleagues used machine learning methods to analyze the Hubble Space Telescope's archives between 2002 and 2021 to measure the impact of satellite trails. The study found that the chances of a Hubble image being contaminated by a satellite rested around 3.7% until 2021 when it jumped to 5.9%, corresponding with SpaceX's unprecedented cadence of Starlink missions (Kruk et al., 2023, p. 265). If 100,000 satellites were put into orbit, image contamination would increase to 50%, halving Hubble's efficacy (Hall, 2023). In a letter to the FCC raising concerns about SpaceX's license amendment, NASA estimated that if the proposed megaconstellation were deployed in full, there would be at least one Starlink satellite "in every single asteroid survey image taken for planetary defense against hazardous asteroid impacts, decreasing asteroid survey effectiveness by rendering portions of images unusable" (Brodkin, 2022). Light reflecting off a single satellite may be some billion times brighter than the celestial bodies scientists attempt to detect and analyze (Lawrence et al., 2022, p. 430). A swelling fraction of research budgets for astronomical observation must be devoted to tracking and mitigation. Individual artificial satellites can ruin image exposures, but treated collectively, the ramifications of orbital (light) pollution are much more dire.

In the worst-case scenario, the consequences of crowding Earth's orbit with artificial satellites are not only disastrous, but essentially irreversible. Spacecraft periodically cease to function correctly, like all machines can. It is not uncommon for satellites to go offline before they can be deorbited into the atmosphere or pushed outwards into so-called graveyard orbits. No longer able to communicate with ground systems, they become uncontrollable hypervelocity projectiles travelling at speeds in the tens of thousands of kilometres per hour. Space environmentalist Moriba Jah explains that "orbital highways are finite in number, and there is a carrying capacity for every single orbital highway that we've yet to measure" (Heilweil, 2023). In addition to rocket upper stages, spacecraft fragments, and chips of paint, defunct satellites contribute to the root problem of the environmental disaster in Earth's orbit: the proliferation of orbital space debris. The volume of trackable near-Earth objects heightened drastically when American and Russian satellites Iridium 33 and Kosmos 2251 collided in 2009 and again from anti-satellite weapons tests by China, the U.S., India, and Russia (Lawrence et al., 2022, p. 433). Whether a collision is accidental or purposeful does not change the nature of the outcome: when objects collide, it creates a larger number of smaller debris fragments. A cascading effect, known as the Kessler syndrome, could eventually occur, where feedback runaway of debris collisions would make the "orbital space around Earth completely inaccessible, even to pass through" (Green, 2021, p. 70). Artificial satellites are a mechanism by which humankind pollutes the non-terrestrial part of our planet, potentially to the point of complete ecological catastrophe.

In the article "Deep Time of Media Infrastructure," Shannon Mattern (2015) recontextualizes communication systems across temporalities. Deep time can help to elucidate the spatial-temporal and cultural-historical context of technologies like the written word, the telegraph, or the railroad and how these information infrastructures contributed to the formation of cities and publics. This historiography of media and networks looks far into the past, where disparate technological systems became entangled, fragmented, superseded, or buried by their environments. Mattern only mentions extraterrestrial infrastructure in passing, but the theory of deep time can be an appropriate theoretical tool to conceptualize the affordances and limitations of technologies deployed in near-Earth space. Unlike the layering of infrastructures under topsoil later revealed by archaeology, defunct space infrastructure will not be obscured by comparable natural processes. Gravitational pull is the only erasing quality in the ecosystem of near-Earth space, the timescale dependent on the orbit and velocity of the object in question. Even if satellite and spacecraft launches ceased tomorrow, in all likelihood, there would be debris in Earth's orbit for millennia. Satellites make clear modern civilization's dexterity to enact command *globally* over space. In the same breath, satellite constellations expose our modern civilizations' inability to adequately mitigate technology risk *intergenerationally*. Of course, Western capitalist and imperialist culture operates on dialectics of expansion, not duration.

A transformation of Earth's atmosphere and sky has already begun. Even before the era of the megaconstellation, reflectivity of space objects had contributed to an estimated 10% increase in the diffuse brightness of the night sky, dubbed the "skyglow effect" (Kocifaj et al., 2021, p. 44). Smaller debris fragments contribute disproportionately more radiance than large and intact satellites. Objects at this scale are more difficult to track, but it is expected that there are around one million centimetre-sized objects that can damage satellites, produce more debris, and reflect more sunlight (Barentine et al., 2023, p. 253). Suppose collisions of this sort are to occur at a higher frequency, which large constellations in crowded orbital shells inevitably bring about. In that case, there will be proportional and irreversible increases in skyglow. As space law researcher Ciara Finnegan notes, the impact of such constellations will be especially detrimental to Indigenous astronomy practices, in "all of the diverse relations and interconnections of all Indigenous Peoples with the sky, universe, and celestial bodies therein" (2022, p. 9). The formation of the stars are used by Polynesian peoples for wayfinding at sea and by the Navajo to tell stories and histories. Indigenous astronomical traditions and knowledge systems are customarily passed through oral tradition—a time-biased and temporally based medium of communication. Satellites and the orbital debris they affect place our scientific and culturally valued dark skies at extreme risk.

Global spanning constellations launch in the spirit of "ending the digital divide" (Starlink, 2023). However, this happens with the potentially irreversible loss of Earth's dark skies and star constellations, a shared environment of incalculable value (Venkatesan, 2023, p. 236). In *Astrotopia* (2022), a critique of the corporate age of space, Mary-Jane Rubenstein writes that Starlink, "like the five hundred years of colonial ventures that produced it, proclaims itself an act of *service*" (p. 117). While the company's megaconstellation is framed as an infrastructure created for the common good of humanity, SpaceX is a business foremost, beholden to investors and the expectation of economic return. Calls from astronomers, Indigenous groups, environmentalists, and others in the concerned public to moderate technology risk in orbit have not tangibly slowed down the rate of satellite launches. It just made NewSpace rethink their approach to public relations. In the introduction to *The Bias of Communication*, Paul Heyer and David Crowley offer an apt characterization of information technologies, such as satellites.

> In today's world, space-biased media in the form of modern electronic communications have assumed unparalleled influence. In the guise of giving greater access to, and democratizing information, they can entrench modes of domination that in some ways resemble what took place in previous epochs. It is the rich and powerful nations able to exploit this technology to its limits who, in the guise of making it available to others, extend their information empires. (2008, p. xxxv)

Telecommunications is essential for global industries to function, but it cannot be overlooked that megaconstellations assure privatized profit at the detriment of our planet's orbit. The aggregate effect of satellites can be categorized as a *tragedy of the commons*, a social dilemma identified by ecologist Garrett Hardin in a 1968 article. Hardin asserts that unmanaged and unregulated access to shared spaces leads to resource depletion and the eventual deterioration of the natural environment in question. Near-Earth space is no exception. However, this region is not polluted by the collective actions of individuals but rather the actions of corporations (Mildenberger, 2019). The FCC authorizes the deployment of satellites in orbital shells on a first-come-first-served basis, arguably in violation of the non-appropriation clause of the OST (Boley & Byers, 2021, p. 5). Specialized regulation for megaconstellations to mitigate orbital space debris has yet to materialize (Petersen, 2022).

Without a well-coordinated and closely adhered-to framework, “we are left with the growing unease of watching the slow-motion inevitability of a preventable disaster in LEO” (Venkatesan, 2023, p. 236). It is through this disaster that Earth’s orbital carrying capacity may be discovered. Hito Steyerl wrote that with the rise of modernity, the linear perspective of space and time was replaced by a perspective of verticality, understood as the stratification and structuration of a society which has been “outsourced to machines and other objects” (2011). Paradigm-shifting technologies, such as satellites, have advanced communication, surveillance, and the extension of power over geographies. But as a result, “time is out of joint and we no longer know whether we are objects or subjects as we spiral down in an imperceptible free fall” (Steyerl, 2011). Our civilization will have worldwide access to low-latency and high-speed internet communications via space infrastructure, but we will obscure Earth’s dark skies and threaten the very possibility of space exploration at all. These are the consequences of our preoccupation with the present moment. The seventh-generation principle of the Haudenosaunee Confederacy is an ancient philosophy that encourages decisions to be made considering the lives of the next seven generations and those of seven generations past. When the following seven generations look upwards to outer space, they will not see the quantity or clarity of stars accessible to the previous seven generations. A disposition towards the spatial, Harold A. Innis would surmise, has induced a vast disregard of the temporal. If the many proposed megaconstellations come to fruition and if disaster does occur, it is plausible that the only visually discernible things in the diffusely brightened night sky will be artificial satellites and/or the Moon, Earth’s only natural satellite.

Including the Moon

Belief systems which involve the Moon predate science, its origins and functions are documented in the earliest religious texts of written tradition (Murray, 2021, p. 21). Lunar origin myths have existed in the spiritual histories of oral cultures for an extraordinarily long time (Buck, 2021). Geopolitical histories of the Moon originated less during the Cold War less than an average human’s lifespan ago. The industrial and commercial history is just beginning. In 1979, the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies, colloquially known as the Moon Agreement, was finalized. The multilateral treaty was created as an international framework that could bridge gaps in definition brought about by technological advances and societal changes since the Outer Space Treaty was signed in 1967.

For one, Apollo had landed astronauts on the Moon and brought them safely back to Earth, fundamentally recontextualizing spaceflight. Although tensions of the Space Race wound down, the nationalism of it all was not lost. Accordingly, the Moon Agreement's twenty-one provisions set the ground rules for longstanding lunar presence, forbidding military bases and affirming the freedom of scientific investigation. At the same time, it also assured environmental protection for the lunar environment, declaring that state parties must take measures to keep the Moon from being microbially contaminated by human occupancy. The Moon Agreement put forward a legal categorization of the Moon generally consistent with the provisions of the OST but notably expanded in scope on the matter of geopolitical equity.

> The exploration and use of the Moon shall be the province of all mankind and shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development. Due regard shall be paid to the interests of present and future generations as well as to the need to promote higher standards of living and conditions of economic and social progress in accordance with the Charter of the United Nations. (1979, Article 4.1)

Unlike the OST, the treaty interpreted what it would really mean for objects in outer space to be considered the shared heritage and province of all humankind. It determined that the territory of the Moon and its natural resources could not become property of a government, a non-government entity, "or of any natural person" (1979, Article 11.3). Profits from those resources, unable to be appropriated, would have to be shared amongst all countries regardless of wealth on the basis of *res communis* (Dolman, 2002, p. 133). In the end, the document was signed by just enough UN member states for it to be turned into international law, but it was not ratified by any spacefaring nations with independent space programs (Rubenstein, 2022, p. 105). Without any practicable influence, the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies of 1979 is, for all intents and purposes, a failed treaty.

Had the treaty been adopted by prominent space actors (United States, Russia, and China), the Moon Agreement would have required the establishment of an "international régime" to "govern the exploitation of the natural resources of the Moon as such exploitation of the natural resources is about to become feasible" (1979, Article 11.5). That moment—the increasingly technologically plausible circumstance of lunar resource extraction and commercialization by a field of international actors—is unfolding in this decade. "The future is there," says Gustavo Medina Tanco, who leads Latin America's first lunar project, COLMENA, "you can consider the Moon a new economy" (Witze, 2023b, p. 426). The budding era of private-public partnership in lunar exploration started in a familiar place: a competition with a grand prize. Between 2007 and 2018, the XPRIZE Foundation and Google as a sponsor offered $20M to the first privately funded company to soft-land a robot on the Moon, have it move half a kilometre, and send a high-resolution picture back to Earth. Like the Ansari XPRIZE for Suborbital Spaceflight, the Google Lunar XPRIZE was created to stimulate commercial, entrepreneurial innovation and lower the cost of entering space. Although the competition ended without a winner, spacecraft from around the world were developed by companies that are now contractors for programs such as Artemis' Commercial Lunar Payload Services (CLPS)—several of the robotic systems have already reached lunar space (Azer, 2020).

Figure 7

Orion's Moon Crater Close-up

Note. Image taken by the Orion spacecraft's optical navigation camera.

In 2019, a small robotic lunar lander called Beresheet, operated by one of the Google Lunar XPRIZE finalists, SpaceIL, crashed into the Moon. SpaceIL still received $1M for touching the surface, becoming the first private entity to do so (Wall, 2019). Only after the mission failure was it revealed that one of the spacecraft's payloads, a digital archive produced by non-profit Arch Mission Foundation, contained life. The group had added thousands of microscopic tardigrades, dehydrated to slow their metabolic processes (Oberhaus, 2019). Tardigrades, also called water bears, are known to science as some of the world's most resilient creatures, able to survive incredibly extreme environments, including the vacuum of outer space. What happened after the spacecraft and stow-away water bears collided with the lunar surface? No one knows for sure. The chances that the micro-animals contaminated some scientifically relevant process of the lunar surface in their dormant state is minute but non-zero (Goldsmith & Rees, 2022, p. 70). To make matters worse, the biological material was added without governmental approval or notification to the Israeli or American teams. "Space agencies don't like last-minute changes," Arch Mission Foundation co-founder Nova Spivak commented after the crash, "so we just decided to take the risk" (Grush, 2019). The non-profit seems to have not broken international space law, as the Arch Mission Foundation faced only short-lived condemnation from the space community, setting a dangerous precedent for NewSpace accountability. A second mission, Beresheet2, is planned to launch in 2025. If anything, the tardigrade affair is a disquieting case study into planetary protection guidelines and Moon regulation, or lack thereof.

Back in 1979, a space advocacy group known as the L5 society had lobbied members of U.S. Congress to oppose the Moon Agreement, arguing that America should not be obliged to follow international regulation and that it would stifle the development of lunar infrastructure if the possibility of corporate profit were erased (Wanjek, 2020, p. 159). No one lobbied on behalf of the treaty. Would a payload of smuggled tardigrades have crash-landed on the lunar surface in an alternate history where the Moon Agreement was ratified by the countries leading space exploration? Again, there is no way to know. The action would have been unlawful, at the very least. The L5 society, which existed at the acme of the space colonization campaign, was formed to promote the outer space ideations of Gerard K. O'Neill and the eventual realization of O'Neill Cylinders. Manufacturing the rotating space architecture requires resources to be stripped from the Moon, asteroids, and other planetary surfaces and slingshot off-world using a mass driver concept (Scharmen, 2021, p. 104). An inability to appropriate raw materials would terminate the supposedly self-sustaining space colonies before the enormous project could get an industrial footing. The O’Neill Cylinder concept would have dissipated over time if it weren't for the patience, affluence, and enterprise of Jeff Bezos.

In an interview given shortly after his 2021 suborbital tour, Bezos spoke to Earth’s fragility and petitioned to “take all heavy industry, all polluting industry, and move it into space” to “keep Earth as this beautiful gem of a planet that it is” (Ruhle, 2021). Here, Bezos borrows lines from his 2019 presentation “Going to Space to Benefit Earth” in which he contended that children would lead worse lives than their parents because they would consume less energy per capita for the first time in history. To create a civilization of “dynamism” and “growth” whose compounding energy consumption need not ever plateau, we must take advantage of the asteroid belt’s virtually limitless resources. The crux of this technological maturation is, for Bezos, the Moon. There is a reason why he calls it a "gift" to humanity. It is technically much easier to get somewhere in the solar system from the Moon than to get to that place from Earth, even though the distance is essentially the same, due to the significantly larger body in Earth having a proportionally larger gravity well. Gravity on the Moon is a seventh of that on Earth. Thus, it requires a fraction of the energy to launch spacecraft—or for any number of manufacturing challenges, such as building giant space infrastructures (Wanjek, 2020, p. 102). In 1984, German rocket-propulsion engineer Krafft Ehrickein said that “if God wanted man to become a spacefaring species, he would have given man a Moon” (Spudis, 2018).

Bezos advocates the O’Neill paradigm for outer space, a techno-optimist framework from the late 1970s and early 1980s, when Bezos was one of O’Neill’s students at Princeton (Davenport, 2018, p. 74). O’Neill designed plans for massive rotating space colonies built with materials from the Moon. There are two gates for entry in realizing this paradigm, Bezos finds: lowering the cost of launch and in-situ resource utilization. Blue Origin’s mission is to build the industrial infrastructure for space so that, one day, the entrepreneurs of future generations (who would be able to “start space companies in their dorm room”) will complete O'Neill’s space settlement utopias (Blue Origin, 2019). Bezos believes there is a binary for the potentiality of civilization—a static future or an abundant one. In this view, “stasis” and “rationing” are humankind’s biggest threats. With O’Neill Cylinders, Bezos proclaims, “We can have a trillion humans in the solar system, which means we’d have a thousand Mozarts and a thousand Einsteins” (Blue Origin, 2019). His remark is so speculative and idealized that it nears fantasy. In reality, the O’Neill paradigm has remained critically unchanged over many decades and in the contemporary global context. The space expansionist discourses that Bezos presents today are a “watered-down version of nostalgia for yesterday’s future” (Scharmen, 2019).

O'Neill and Bezos' future of abundance rely on the generation of virtually unlimited energy, which is impossible on a limited planet. Blue Origin recently announced that they had manufactured solar cells from simulant lunar regolith, the dusty material which covers the Moon’s surface. Blue Alchemist, as the technology is named, “can scale indefinitely, eliminating power as a constraint anywhere on the Moon” (Blue Origin, 2023). NASA awarded Blue Origin $34.7M for in-situ resource utilization-based power—one of eleven companies which received funding to develop technology for long term lunar exploration (NASA, 2023). Near the end of his 2019 presentation, Bezos unveiled Blue Moon, a prototype of Blue Origin’s lunar lander that is in development. It formed the basis of part of the Integrated Lander Vehicle, created in partnership with Lockheed Martin, Northrop Grumman, and Draper Laboratory, proposed to NASA as a Human Landing System (HLS), to land Artemis astronauts on the Moon.

However, in 2021, NASA awarded SpaceX the HLS development contract worth $2.9B. HLS is the mode of transport to descend astronauts from lunar orbit to the surface for Artemis III and IV (Witze, 2022). These missions are slated to land at one of thirteen candidate landing sites at the lunar South Pole, near permanently shadowed regions (NASA, 2022a). The vehicle SpaceX proposed was a Starship variant called Starship HLS, beating out the Blue Origin-led National Team. Two contracts had been anticipated, as is NASA’s tendency towards redundant systems, but Congress only allocated enough funds for a sole-source selection. “NASA veered from its original dual-source acquisition strategy due to perceived near-term budgetary issues” Bezos penned an open letter to NASA Administrator Nelson with an offer to bridge the funding shortfall by waiving $2B of payments, “this offer removes that obstacle” (Bezos, 2021). Blue Origin unsuccessfully protested to the Government Accountability Office and took NASA to the U.S. Court of Federal Claims over the lunar lander decision, but the judge ultimately ruled in favour of the defence (Sheetz, 2021). In 2023, NASA announced that the second iteration of the Blue Origin-led National Team (now in participation with *Boeing*, Draper, and Lockheed Martin) was selected for the second HLS development contract. Blue Moon is the lunar lander architecture for Artemis V, scheduled for 2029 (Foust, 2023b). The fixed-price award is valued at $3.4B, but typically, Blue Origin plans to invest even more internally.

A year before the initial HLS selection, in 2020, the China National Space Administration (CNSA) directed the Chang'e 5 moon lander to deploy the Chinese flag on the Moon, making it the second nation to do so. The red five-starred flag was constructed with a composite material designed to withstand the severe lunar environment without fading (David, 2020). Chang’e 5 is the most recent mission of the Chinese Lunar Exploration Program, or Chang'e project, its namesake is derived from Chinese mythology. Chang’e is the goddess of the Moon. It is composed of four initial phases. The first was to reach lunar orbit, completed by Chang'e 1 and 2 in 2007 and 2010, respectively. Soft-landing and roving were the second phase, with the landing of Chang'e 3 in 2013 and then Chang'e 4 on the far side of the Moon. In 2020, Chang'e 5 performed Phase III, a lunar sample-return mission—the first since the Soviet Union's *Luna 24* in 1976. Spectra observations and return samples showed evidence of lunar water, which "is expected to provide support for future human lunar in situ resources" (Liu et al., 2022, p. 2). China's remaining scheduled Chang'e lunar missions focus on landing sites in the lunar South Pole to establish the International Lunar Research Station (ILRS) as soon as 2036 (Hu et al., 2023). ILRS is a joint project with Roscosmos. China plans crewed lunar landings by 2030 (Shepherd, 2023), and construction of the new rockets in the Long March fleet, the spacecraft, and the landers has been set into motion (Jones, 2022b).

There is a fundamental problem in these concurrent lunar programs' plans: several of the proposed landing zones of the Artemis program and the Chang'e project, such as Amundsen and Malapert, overlap (Jones, 2022a). Both spacefaring superpowers have their sights set on the same regions of the Moon, but more specifically, on what is to be found in the cold traps of its permanently dark craters: concentrations of lunar materials formed in the early solar system (Elvis et al., 2021, p. 4). Water ice deposits, through extraction and electrolysis, can produce air for breathing, water for drinking, and even rocket fuel (Li et al., 2018). Liquids are a burdensome and thus expensive payload to blast through the atmosphere. Access to water in space makes habitation significantly more achievable. With the potential to sustain "lunar habitats and even entire lunar industries in the future," the economic value of these resources is incalculable (Mehta, 2022). Research suggests that the Moon contains rare Earth elements such as yttrium and scandium that are used in manufacturing electronic devices—a global market dominated by China (Elvis et al., 2021, p. 7). Lunar regolith also contains helium-3 isotopes accumulated from billions of years of high-energy particles cast out by solar wind (Vidal, 2022). What makes helium-3 reserves so valued is their potential to be used as fuel in nuclear fusion reactors (Vidal & Halloy, 2021). Even though helium-3 fusion technology is years if not decades away, American commentators have already pronounced that the "country that controls the source of energy that keeps technological civilization running will control the Earth" (Whittington, 2022). But once the resource has been "mined and used, it's gone for good" (Wanjek, 2020, p. 168). The possibility of dual presence on the Moon—and dual intent to exploit lunar materials for science, politics, or profit—puts international space diplomacy in jeopardy.

Former President Donald Trump signed an executive order in 2020 which affirmed Americans' right to the "commercial exploration, recovery, and use of resources in outer space" as the "United States does not view it as a global commons" (Exec. Order No. 13914, 2020). It eliminated any legal ambiguity shrouding commercial activity on the Moon, explicitly objecting to the 1979 Moon Agreement. The directive was in line with the Spurring Private Aerospace Competitiveness and Entrepreneurship (SPACE) Act of 2015, which gave U.S. space-mining companies the green light to exploit "space resources" (Williams, 2020). Dmitry Rogozin, then director general of Roscosmos, equated the 2020 order to U.S. invasions in the Middle east: "only another Iraq or Afghanistan will come out of this" ("Rogozin compared US plans", 2020). Shortly thereafter, NASA announced the Artemis Accords, a series of agreements drawn up (unilaterally) to codify a legal framework for civil space exploration (Manning, 2023). If the provisions are accepted by a significant number of spacefaring nations, the Accords will "make the United States—as the licensing nation for most of the world's space companies—the de facto gatekeeper to the Moon, asteroids, and other celestial bodies" (Boley & Byers, 2020, p. 174). Being a signatory of the Accords is a prerequisite for participation in Artemis—it is a *fait accompli*. More than twenty-five nations have signed thus far.

Effectively, the Artemis Accords have enabled the U.S. to dictate the terms of lunar mining before or at the exclusion of other countries (Patel, 2020). Its language affirms the permissibility of commercial space mining and commits to using "safety zones" to limit interference between entities extracting lunar resources (*The Artemis Accords*, 2020, p. 5). Some concerns are that territorializing the Moon through these zones could amount to national appropriation. Media commentators in China likened the Accords to the enclosure movement of 18th-century England, in which public lands were made private (Ji et al., 2020). Provisions are being created for lunar development, governance, and environmental protection, but they are futile without other major parties' participation. With these unrelated space exploration projects unfolding simultaneously, geopolitical lines are being drawn in the lunar sand. On one side, NASA, ESA, CSA, JAXA, and most other spacefaring nations, on the other, CNSA and Roscosmos. "It is a fact: we're in a space race," claimed NASA Administrator Bill Nelson, "and it is true that we better watch out that they don't get to a place on the Moon under the guise of scientific research" (Bender, 2023). For the figurehead of Artemis, the geopolitical implications of a China-Russia lunar base agreement are extensive.

Democratically elected governments' space programs are, at four or eight-year intervals, subject to the space policy of the new political leadership. Whereas the state-owned space agencies of authoritarian nations can plan long-term space programs with little concern for changes in administration (Goswami, 2021). The ILRS partnership is a strategic mechanism, but the ongoing Russo-Ukrainian War will have detrimental effects on Russia's space activities. Back-to-back coolant leaks in Roscosmos spacecraft, purportedly caused by meteoroid strikes, opened speculation that recent technical malfunctions in the Soyuz system are a symptom of a larger problem (Skibba, 2023). Furthermore, the seizure of Roscosmos spaceport assets in Baikonur by the Kazakh government due to unpaid debt indicates that the space agency may be coming apart at the seams (Williams, 2023). In contrast, China has made tremendous technological advancements at an expeditious rate. China originally planned to join in the ISS partnership until 2011, when the U.S. Congress passed the Wolf Amendment, prohibiting NASA from cooperating with China or any Chinese-owned company (Ward, 2019, p. 105). Since then, the nation has completed its own outpost in LEO, the Tiangong (*Heavenly Palace*) Space Station, and sent robotic spacecraft to Mars (Jones, 2021). The People's Republic of China has swiftly matured into a dominant spacefaring nation, its virtually independent lunar program rivalling that of America and its international partners.

"It is a different kind of race than we had in the 1960s," says planetary physicist Philip Metzger, "because it's not so much about national prestige as it is about the future of economic activity in space" (David, 2023). Artemis is publicized as a space program "for all humanity" while synchronously being the mechanism of a “space race” with China. One of these invocations must necessarily be a distortion of the truth. When the United States and all other major spacefaring powers were presented with a framework that ensured lunar operations would be carried out for “the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development,” they opposed (Article 4.1, Moon Agreement, 1979). Space’s economic and geopolitical value is too high and rapid innovation from the commercial sector is too indispensable. It is difficult to disassociate the round one HLS development award from the mutable political discussion about Artemis being a Moon-to-Mars project. Investment in Starship as a Mars-rated vehicle for lunar landing can be seen as a strategic funding move for NASA. In space policy and appropriations on Capitol Hill, it is up for interpretation if the Moon is meant to be, as Casey Dreier puts it, a cornerstone for space exploration or a stepping stone to Mars (2020). Artemis depends on close partnership with private actors with ambitions and resources independent of NASA contracts, and the red planet is SpaceX’s raison d'être. The promise of the Moon is not only found in its relative proximity and features such as water, ice, helium-3, or for solar energy potential. How humankind extends its reach into lunar space dictates how it may expand across the solar system, as one civilization or in its national, political, and corporate parts.

And Other Celestial Bodies

A discussion about crewed exploration and near-term habitation on other celestial bodies is ostensibly a discussion about Mars. As far as we know, the planet’s thin atmosphere and dusty surface is currently home only to robots—many of which are defunct, and some of which are debris. Four vehicles across three systems are still in operation on the surface: NASA’s Curiosity rover (2012), NASA’s Perseverance rover and Ingenuity helicopter (2021), and CNSA’s Zhurong rover (2021). Various scientific instruments on these vehicles inspect geological, atmospheric, and general planetary processes to assess how the world's past environment with oceans and rivers may have supported favourable conditions for microbial life. NASA has taken to the mantra “follow the water” (Tillman, 2018). The systems also collect data to determine the viability of crewed missions, giving planners a rounded idea of what human experience may be on the surface. The collected findings expose Mars' natural history and its potentially unnatural future. Robotic technology on Mars is a medium which extends technological reach, making provisions for human exploration and expansion.

Understanding Media (1994) is media philosopher Marshall McLuhan’s most prominent work containing his most durable media theory: “the medium is the message” (p. 7). First published in 1964, the book introduced the notion that technological mediums, the tangible receptacles for social information, influence social, industrial, and political functions (1994, p. 6). McLuhan found them to be an augmented and patterned part of human activity within a mechanized culture becoming increasingly globalized and electronic. The social effects of mediums are overlooked, and attention is instead placed on the content of the media itself. McLuhan believed mediums to be extensions of the physical body and its senses, broadening the scope of what a medium is considered to be. Telescopes are an extension of sight, the wheel is an extension of the foot, clothing and heat-control mechanisms are an extension of skin (1994, p. 123). The addition of new media tools, he argued, remakes individual experience.

McLuhan's leading example of the electric lightbulb as a medium composed of absolute information but devoid of any immediate content remains salient (1994, p. 15). The lightbulb did not invent light. Rather, it invented new contexts and spaces in which illumination could serve a purpose. "It is not until the electric light is used to spell out some brand name," McLuhan wrote, "that it is noticed as a medium" (p. 9). As the innocuous modality was widely adopted into practice, it reshaped our human associations and relationship to darkness—to *things* that can be illuminated. The medium's features are what make possible the awareness and capability of its residing media. Medium-specificity and its relation to patterns in the social world was not exactly an original connection. McLuhan borrowed heavily from Innis in this regard (Babe, 2000, p. 299). However, McLuhan accessed mainstream platforms in a way Innis could not. At the time, McLuhan represented "an apocalyptic vision, an eschatological prediction about the future that can quell our frequently ambivalent feelings about ourselves and our inventions" (Carey, 1969, p. 304). Part celebrity intellectual and part doomsday prophet, McLuhan keyed into the cultural zeitgeist to forecast how technology would mediate interpersonal communication, maintaining that the medium holds the true answers to material change in society.

A common critique of *Understanding Media* is that the text did not make space for cultural difference or for structural and economic imbalances at the institutional level (Kroker, 1984, p. 80). The McLuhanian subject is a universalized one—the Western man. In *Re-Understanding Media* (2022), edited alongside Rianka Singh, Sarah Sharma acknowledges McLuhan's short-sightedness but chooses not to disregard his media theory as being too technologically deterministic or reductive of social effects. Instead, *Re-Understanding Media* inlays McLuhan-derived "medium-specific techno-logics" into the contemporary setting to trace the overlapping vectors of technology and identity, disclosing how power operates in culture (Sharma, 2022, p. 8). The uncritical application of McLuhan's work into the modern technological terrain brings about the replication of his ideological faults of assuming a universalized subject, a rhetoric commonly espoused by individuals "who remain willfully blind to the realities of the uneven technological futures they are increasingly responsible for" (Sharma, 2022, p. 4). Tech entrepreneur Elon Musk is one of these individuals.

Musk became an outspoken proponent for interplanetary travel in 2001, around the same time he became involved with the Mars Society, a non-profit organization founded by Robert Zubrin that advocates for the colonization of Mars. A year later, Musk would incorporate SpaceX. The entrepreneur believes that human history will "bifurcate" into two possible outcomes: "One path is we stay on Earth forever, and then there will be some eventual extinction event [...] the alternative is to become a space-bearing civilization" (Musk, 2017). Congruent with the Zubrin paradigm of space settlement, in which humans are "stewards and carriers of terrestrial life" (Zubrin, 1999, p. 226), it is Musk's ambition to transport one million people aboard a fleet of Starships to form a permanent and eventually self-sustaining city on Mars. The terms of service for SpaceX's Starlink requires its users to recognize "Mars as a free planet and that no Earth-based government has authority or sovereignty over Martian activities" and that any "disputes" are to be settled "through self-governing principles, established in good faith, at the time of Martian settlement" (Brown, 2020). The internet service clause seems a bizarre attempt to set precedent for operating outside the bounds of international space law.

While Zubrin theorized the "significance of the Martian frontier" as a "driver for technological progress" in the 1990s (1999, p. 123), science fiction author Kim Stanley Robinson actualized it. *Red Mars* (1992) details the colonization of Mars as overpopulation causes sociopolitical degradation on Earth. The novel is one Zubrin and Musk's favorites (Fernholz, 2018, p. 46). Its plot pulls together many pressing ethical concerns about space settlement into a cohesive fictional story, contending with planetary immigration and transnationalism, control of resources, and violent conflicts of faith and governance. It also addresses the creation and fracture of Martian identity into different sects: the Greens, who want to transform the planet's ecology by terraforming, and the Reds, who want to maintain its natural state. To some readers, it is a cautionary tale. For others, it is a blueprint. On the cover of the first edition, Arthur C. Clarke is quoted saying that *Red Mars* should be "required reading for the colonists of the next century" (1992). Musk regularly draws upon fantasy in his proposals, popularizing the concept of detonating nuclear fusion devices over the Martian poles to create tiny pulsing "suns". This idea states that the heat generated would release carbon dioxide to thicken the world's atmosphere (Herron, 2019, p. 555). Even overlooking the technological implausibility and the massive legal and ethical repercussions of terraforming other planets, researchers concluded that if all CO2 deposits were expended on Mars, the resulting change to the planet's warmth and atmospheric pressure would be negligible (Walkowicz, 2018). Nevertheless, SpaceX has since sold "Nuke Mars" T-shirts.

As the founder and CEO of SpaceX, Musk sees Mars as a backup planet for humankind, summoning an unavoidable, species-ending disaster on Earth as the driving force for space expansion. He refers to Starship as "modern Noah's Arks" (Musk, 2022). Common in NewSpace rhetoric, there is an "interplay of optimistic and pessimistic registers in which these extraplanetary imaginaries are expressed" (Tutton, 2020, p. 421). The convenience of the catastrophe narrative, such as a planet-killer asteroid or misaligned Artificial Intelligence, is that it permits Musk to communicate the necessity of interplanetary habitat expansion while evading or downplaying current global crises that are exacerbated by acute wealth disparity. A tweet from Senator Bernie Sanders pointed out that, put together, Jeff Bezos and Elon Musk hold more wealth than the bottom 40 percent of people in the United States. "That level of greed and inequality is not only immoral," Sanders wrote, "it is unsustainable" (2021). Musk tweeted in response that he is "accumulating resources to help make life multiplanetary & extend the light of consciousness to the stars" (2021). This invocation to *extend* consciousness to a new world is the basis of Musk's Mars-centric expansionist techno-logic.

Sociologist Karl Palmås and colleagues refer to the sociotechnical forecasting of mass extinction on Earth and the utopian space colony as the emergence of a "capitalist eschatology" (2022, p. 1). It is an inevitable end-time "made operative in contemporary capitalism" wherein the expense of space migration technologies is projected as an investment (Palmås et al., 2022, p. 3). The proposition is utilitarian in that it prioritizes an infinite number of hypothetical future people over the lives and palpable experience of those in the present. Existential risk philosopher Toby Ord refers to this view of the future as "longtermism" (2020, p. 46). What capitalist eschatology does, however, is leverage doomsday rhetoric to advance themselves in the modern terrain of political economy. Literary theorist Fredric Jameson is attributed the popular aphorism which pairs the apocalyptic with the economic.

> Someone once said that it is easier to imagine the end of the world than to imagine the end of capitalism. We can now revise that and witness the attempt to imagine capitalism by way of imagining the end of the world. (2003, p. 76)

The ideology of techno-utopianism and the end-of-the-world are two sides of the same coin. Centi-billionaire owners of space companies must negotiate both sides, communicating a dire planetary need for expansion *and* the promise that their commercial ventures will assure survival in space. To legitimize SpaceX's mission as a universalizing safeguard, Musk conveys that creating life support systems on Mars—or the possibility of terraforming its environment—is more practicable and desirable than directly addressing Earth's present and near-term existential risks. In *Capitalist Realism* (2009), cultural critic Mark Fisher writes that capitalism "seamlessly occupies the horizons of the thinkable" (p. 8). The perceived lack of viable alternatives has permeated social consciousness so thoroughly that relocating humanity to a different planet to evade capitalism-induced catastrophe is a tenable discussion.

The failure of Musk's vision for SpaceX and of the Zubrin paradigm is that, as journalist Shannon Stirone puts it, "Mars is a hellhole" (2021). The planet is exceedingly inhospitable—the atmospheric volume and gravity is a fraction of Earth, and the air is impossible for humans to breathe. No longer having a global magnetic field or ozone layer to deflect energetic particles, living organisms on Mars are unprotected from space radiation. "There's going to be some risk of radiation, but it's not deadly," Musk said during his presentation on the Starship system architecture and the challenges for permanent Mars presence at the International Astronautical Congress in 2016. "There will be some slightly increased risk of cancer, but I think it's relatively minor [...] the radiation thing is often brought up, but I think it's not too big of a deal" (Paoletta, 2018). Travel-time to Mars takes approximately nine months one way, with launch windows occurring every 26 months when the two planet's orbits are closest (Dobrijevic & Tillman, 2023). During transit, astronauts and electronics will be subject to two types of radiation: solar energetic particles from our Sun and galactic cosmic rays received from outside the solar system (Dorrian & Whittaker, 2018). Nathan Schwadron and colleagues discovered that the rate of galactic cosmic rays has fluxed to unexpectedly high levels in the current solar cycle period (when the Sun is relatively inactive and its magnetic field relatively weaker) (2018, p. 302). Exposure to radiation damages DNA in the cells of the body, it is undeniably hazardous. If humans are to venture into deep space for any duration, space radiation is, in fact, a big deal.

As it stands, the best chance for habitability on Mars is to burrow underground. The people who may live or be born in a space environment (or on any celestial body other than Earth) will always be utterly dependent on technology. If long-term presence is to be established on Mars and a city/civilization becomes truly self-sustaining, the technological mediums supporting life can and will "determine the social order in unanticipated ways—in particular, they change social conceptions of time, space, and distance and more fundamentally what it means to be human and in relation to one another" (Sharma, 2022, p. 9). A Martian population would be more radically different than any two groups on Earth; the ubiquity and necessity of machines for basic survival on other planets defining the structures and patterns of being. This includes implementing technologies for human enhancement and engineering the genome to protect against the effects of cosmic radiation or micro-gravity. Like the other sites of tension and moral ambiguity in space expansionism, bioethics questions "whether the end justifies the means, even if that end is the survival of our species" (Szocik, 2023, p 4). McLuhan's evaluation that "technology is part of our bodies" takes on an especially literal meaning at the confluence of biology and technology for new associations, modifications, and possibilities (1994, p. 68).

To see how a space settlement as envisioned by Bezos or Musk might function in practice, one only needs to look to the factory floor. Companies of both billionaires have been accused of labour rights violations and unsafe work environments (Nesvold, 2023, p. 124). Hundreds of SpaceX employees signed an open letter which described Musk's "behavior in the public sphere is a frequent source of distraction and embarrassment" and requested that the company separate itself from his personal brand (Mac, 2022). Employees who organized and distributed the letter were promptly fired (Scheiber & Mac, 2022). How dissenting opinions would be treated a world away from regulatory oversight or effective redress is a significant consideration (Francis, 2023). To conceptualize the hypothetical space settlement, one needs to think not only how it will function but how it will invariably dysfunction. There must be an ample consideration of "the failure mode of the space economy" (Nesvold, 2023, p. 123). Mary-Jane Rubenstein questions if "we really expect that the notoriously inhumane industries of mining, manufacturing, and global retail will suddenly establish decent working conditions on literally uninhabitable planets?" (2022, p. 158). For all its discursive appeal, space expansionism is not for all humankind's betterment. NewSpace, at its very foundation, is built through a flourishing wealth-gap and the systematic, inequitable distribution of resources for profit.

2018 saw the test launch of SpaceX's Falcon Heavy. In orbit, the rocket's payload was revealed to be Musk's personal Tesla Roadster (Mosher, 2018). The car contains a disc made by the Arch Mission Foundation (later responsible for the 2019 Moon-tardigrade incident) (Taylor, 2018). On the disc is a copy of Isaac Asimov's *Foundation* novel trilogy. *Foundation*'s plot is that a "psychohistorian" predicts the fall of a galaxy-spanning empire and takes steps to rebuild society after a period of civilization decline. His literary inspiration unambiguous, Musk claims he will make life multiplanetary so that there is "somewhere else to bring civilization back and perhaps shorten the length of the Dark Ages" (Space Policy and Politics, 2018). Later that year, having sent his cherry-red sports car toward Mars, Musk tweeted a picture of Marshall McLuhan without any caption. The connotation was clear enough: the medium is the message. Media critic James W. Carey wrote on McLuhan in 1969, his words prescient and even transferable: "when man's relations with machines and technology seem more durable and important than their relation to one another, McLuhan finds man's salvation in the technology itself" (1969, p. 306). At a moment in history when humankind's future feels unpredictable, the advancement of spacecraft technology and drastically lowering costs for reaching orbit and leaving planet Earth extend a message of hope to space expansionists. Salvation through innovation is SpaceX's innate message. Mars is the medium.

Figure 8
Falcon Heavy Demo Mission

Note. The Tesla Roadster payload, on Falcon Heavy's demonstration flight.

Elon Musk may be the Marshall McLuhan of our time, just not in the way that he might like to think. "The meaning of McLuhan is not in his message, his sentences, but in his *persona* as a social actor, in himself as a vessel of social meaning" (Carey, 1969, p. 303). Like McLuhan, Musk is the face of emergent technology in a metamorphosing society, his character fulfilling a role in a culture uncertain about what the planetary future holds. The ever-confident projection of seeing a sovereign city on Mars within the century is widely received, but it is hollow. What McLuhan communicated in the 1960s and 70s was "a modern myth, and like all myths it attempts to adjust us to the uncomfortable realities of existence" (Carey, 1969, p. 306). The techno-utopian vision to extend the light of consciousness into space at the end-of-the-world is also a myth. Except, it is not about adjusting to life's uncomfortable realities; it is about escaping them. For all practical purposes, Musk's proposal of a multiplanetary civilization in the near-term is a "masquerade, mimicking the shape of a radical response to a serious crisis while being devoid of the social and political content required to address it" (Davidson, 2022, p. 61). In future generations' best interests, and for those of today, we ought to "concentrate on maintaining the habitability of the Earth," as Kim Stanley Robinson articulated two decades after *Red Mars*' release. "Until we have solved our problems here, Mars is just a distraction for a few escapists, and so worse than useless" (Mogensen, 2022).

Conclusion

The way to see how beautiful the Earth is, is to see it as the Moon. The way to see how beautiful life is, is from the vantage point of death.

— Ursula K. LeGuin, *The Dispossessed*

In the grand scheme of things—of the many futures imagined and enterprises advocated for by space expansionists—humankind has accomplished relatively little in outer space. Since the space age began with *Sputnik* in 1957, twelve people have walked on the Moon over a handful of missions, and only several hundred have experienced weightlessness in Earth orbit. These metrics are constantly changing, on an up-and-to-the-right trajectory. Characterized by renewed “military rivalry and very deep-pocketed private-sector activity,” we may be on the verge of a second boom in the age of space (Deudney, 2020, p. 22). Much actionable information will be gleaned from NASA's upcoming crewed missions in the Artemis lunar program, in its rivalry with CNSA’s Chang'e project and its partnerships with Big Aerospace or private commercial entities—most notably SpaceX and Blue Origin. Tens of billions of tax-payer (and now investor) dollars have been spent to send people, science experiments, and flags back to the Moon. It will undoubtedly cost many billions more to realize a permanent lunar base and orbiting lunar space station, let alone a sustained human presence on Mars.

In *The End of Astronauts* (2022), astronomers Donald Goldsmith and Martin Rees argue that the ardent need for crewed exploration in outer space is based less on merit and more on psychology (p. 17). There is a long-standing belief that astronauts and cosmonauts are more effective than robots even though keeping people alive in space is extraordinarily more technically difficult and accompanied by a commensurate increase in cost. Despite the knowledge provided by automated spacecraft throughout the space age, they do not generate the same public interest or fund allocation as crewed spaceflight does. Humans are more adept than machines in a multitude of ways, but Goldsmith and Rees forecast that over the next few decades, “robots and artificial intelligence will grow vastly more capable, closing the gap with human capabilities and surpassing them in ever more domains,” diminishing the demand for astronauts (2022, p. 146). Development in automation and machine-learning will open the decision as to whether or not “humans ride along, viewing themselves as explorers, adventurers, or colonizers” (2022, p. 146). The sociopolitical problems brought about by emergent and dominant technology may be either alleviated or worsened by the introduction of, or interaction with, other technologies. The contours of the space economy will certainly be further recontextualized over time, likely by people and machines that do not yet exist.

There will always be a human impulse to forecast the future, on Earth and off it. However, it is a fallacy to see the future as a place that we will invariably conquer with the advancement of spacefaring technologies. Expansion of habitat into space is a techno-utopian myth that promises our space-biased civilization symbolic immortality. Taken seriously, the danger and extremity of the outer space environment fundamentally troubles the pliable concept of extending the light of consciousness across the solar system. Ecofeminist philosopher Donna J. Haraway writes that in our singular human experience, “we know both too much and too little, and so we succumb to despair or to hope, and neither is a sensible attitude” (2016, p. 4). A move-fast-and-break-things ethos may bring about technological innovation, but, in space, it will likely be associated with suffering. Discursively, the potentialities of death (existential risk and mass extinction) are also regularly exercised, but usually as a means to divert from the current realities of systemic wealth inequality and unsustainable industry practices. These eschatological claims, which invoke the end-of-the-world, reveal that space advocacy and rhetoric have fostered a technology-oriented, quasi-religion of outer space.

Even though it can be difficult to parse out the fictional narratives and speculative science, space expansionist dialogues and actions have material outcomes. The aggregate effects of the private space industry, motivated by virtually infinite resources and profits, will irrevocably alter the lived experiences and ecologies shared by all humankind: Earth's orbit and dark skies, the Moon, Mars, and beyond. National and international space policy is drafted in relation to society's understanding of and engagement with the actors that plan to extract and exploit celestial bodies in outer space for individual economic gain. Under late-capitalism, one can trace the shifts in technology and society by following the money. This is true, but an adjustment in wording extends this line of thinking further: follow the infrastructure. Watch as infrastructure is developed into modern arenas, when new systems become progressively more efficient and versatile. Simultaneously, notice infrastructure as it decays, when those systems deteriorate and programs atrophy from internal or external forces. See where the money goes and what exciting places scientific advancement and progress may take humanity, but also pay attention to the places that are abandoned or marginalized in the absence of those resources. See what parts of our planet and our civilization are left behind.

The aim of this thesis is to contribute to the scholarly project of critically assessing space exploration and migration through Earth's inequitable present and the uneven theoretical futures of indeterminable geographies. Whether it is conceptualized as ahead or behind, the terrain of the technological future requires serious cross-disciplinary ethical deliberation. Further study into the shifting topographies of power in space is needed, especially through frameworks that analyze the cultural dimensions and contradictions of our socio-technological issues. Some of these issues, such as the settlement of Mars, require deep bio-ethical and environmental consideration of how we may eventually sustainably conduct ourselves. Other issues, such as the exponential proliferation of space debris, require an immediate change to the ways we are presently unsustainably conducting ourselves. Between these two ends of the spectrum is our activity on the Moon, a consequential location for our world's societies and economies, our ontologies and epistemologies. When contending with the dangerous idea that expansion into space and time is a conduit for infinite capitalist growth, it is necessary to both historicize and contextualize the current conjuncture. Accepting or preventing these futures in space will dictate what comes next for humankind, our technological civilization, and the light of consciousness. Sooner or later, or as an ongoing process, we will face the consequences of our decisions.

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