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Course of Exogeography, Astropolitics And Space Economy

STRATEGIC EXO GEOGRAPHY AND
POLITICAL-ECONOMIC MODELS FOR
MARTIAN GOVERNANCE: LESSONS FROM
EARTH, RISKS AND PROPOSALS

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Index

Abstract	2
1. Introduction	3
2. Political–Economic Foundations and the Definition of Exogeography	10
2.1 What Is Exogeography? A Critical Definition	10
2.2 Theoretical Relevance of Exogeography within the Political Economy of Space.....	12
2.3 Integrated Theoretical Frameworks	15
2.4 Methodology	17
3. Strategic Geography and Governance of Mars.....	20
3.1 Why Geography Matters: Earth–Mars Parallels in Space Geopolitics.....	20
3.2 Strategic Exogeographic Elements	24
3.3 Governance Model for an early outpost.....	30
3.4 Case Study: The Antarctic Treaty System	40
4. Economy, Geography, and Sustainability	48
4.1 Cost–Benefit Analysis.....	48
4.2 Financing Models.....	54
4.3 The Influence of Martian Geography on Economic Models..	60
4.4 Economic Lessons from Antarctica	67
4.5 Risks of Economic Collapse	73
Conclusions	80
Bibliography.....	85

Abstract

The prospect of establishing a permanent human settlement on Mars has transitioned from science fiction to a technological imminence, yet this engineering progress has significantly outpaced the development of the necessary political and economic frameworks. This thesis addresses that critical disparity by introducing the concept of Exogeography, an analytical lens that examines how terrestrial power dynamics and socio-economic structures are projected onto extraterrestrial environments. By moving beyond traditional geopolitical models, the research identifies a vertical hierarchy of power defined by the control of the High Boundary, where the moon Phobos functions as a strategic panopticon capable of dominating the planetary surface. The study further reveals a fractured planetary geography characterized by a hemispheric dichotomy, forcing a strategic trade-off between the resource-rich Northern Lowlands, essential for economic autonomy, and the fortified lava tubes of the south, which offer necessary protection against radiation.

This physical fragmentation creates a severe risk of social stratification and the emergence of a Company Town governance model, where private corporations could leverage their ownership of life-support systems to supersede human rights and impose a form of lethal tyranny through restrictive terms of service. To mitigate these existential risks, the thesis proposes a dual strategy of legal suspension and economic localization. It argues for the implementation of an Antarctic Exception, adapting Article IV of the Antarctic Treaty System to decouple operational occupation from territorial sovereignty, thereby preventing the settlement from devolving into a private fiefdom. Economically, the research advocates for a transition toward Exogeographic Sovereignty, utilizing a full reserve banking system and a localized currency anchored to the settlement's physical carrying capacity. This approach aims to break the logistics trap of Earth dependency and prevent the extraction of Martian wealth by terrestrial financial institutions, ultimately concluding that the creation of a resilient and free Martian polity requires the proactive design of institutions that prioritize socio-ecological reproduction over commercial extraction.

1. Introduction

The human narrative has consistently been one of relentless exploration and expansion, a testament to an innate curiosity that propels us beyond familiar horizons. From the earliest migrations across continents to the audacious voyages of discovery across vast oceans, humanity has sought to understand, inhabit, and often, to transform new territories. In the 21st century, this enduring impulse has found its most ambitious expression in the aspiration to establish a human settlement on Mars. The red planet, long a subject of myth, scientific inquiry, and vivid science fiction, is now transitioning from a distant enigma to a tangible frontier for human endeavour. Figures like Elon Musk, through SpaceX, articulate a compelling vision of making “life multiplanetary” and establishing self-sustaining cities on Mars within decades, a proposition that, while ambitious, is increasingly supported by significant technological advancements and investment (Mukundan et al., 2023; Young & Docherty, 2025). This burgeoning interest signifies a critical juncture in human history, shifting the discourse from the hypothetical if to the immensely complex how of achieving a sustainable, cooperative, and long-term human presence on Mars.

However, the trajectory towards Martian colonization is not a simple, linear path paved solely by scientific and engineering triumphs. While breakthroughs in propulsion, life support, and habitat design are accelerating, the realization of this grand vision is profoundly complicated by a labyrinthine network of political and economic obstacles. The advent of the new space era, characterized by unprecedented private sector involvement and a fundamental re-evaluation of traditional state-centric space programs, signifies more than just a technological revolution. It represents a potent re-articulation of terrestrial power dynamics, economic imperatives, and socio-cultural constructs onto an emergent cosmic stage (Dunnett et al., 2019; Gonzalez, 2023). Consequently, the challenges confronting Martian colonization extend deeply into the realms of international relations, geopolitical competition, global economic structures, legal ambiguities, and profound ethical dilemmas. Addressing these interwoven complexities necessitates an inherently interdisciplinary approach, drawing extensively from international political economy, critical geography, space law, ethics, and organizational theory (Giordano, 2025c).

This thesis is predicated on the foundational argument that the ultimate viability and success of establishing a human settlement on Mars will depend not exclusively on engineering prowess, though undeniably crucial and steadily advancing, and significantly more on humanity's collective capacity to navigate, negotiate, and mitigate the complex political and economic friction points inherent in such a grand undertaking. The annals of terrestrial exploration and colonization offer a rich, albeit often cautionary, tapestry of historical precedents. These narratives vividly demonstrate how unchecked competition for resources, ambiguous or non-existent governance frameworks, and unsustainable economic models can precipitously lead to exploitation, systemic conflict, and ultimately, the failure of colonial endeavours (Young & Docherty, 2025). Therefore, to ensure that humanity's future on Mars is not a mere replication of Earth's past mistakes, characterized by the projection of existing inequalities and conflicts onto a new celestial body, a proactive, holistic, and critically informed examination of these impending obstacles, alongside the strategic identification of actionable solutions, is not merely advantageous but imperative.

The core problem addressed by this thesis is the substantial and widening disparity between the escalating technological feasibility of Martian colonization and the starkly underdeveloped, fragmented, and often contradictory political and economic frameworks necessary to support such an endeavour sustainably and equitably. On one hand, private enterprises like SpaceX and Blue Origin are relentlessly innovating, developing reusable heavy-lift launch vehicles and proposing ambitious timelines for human missions, while state agencies like NASA and ESA are meticulously researching advanced life support systems, in-situ resource utilization, and radiation shielding (Bushnell, 2021; Neukart, 2024). The very physics of interplanetary travel and long-term extraterrestrial survival are being progressively conquered. On the other hand, fundamental questions concerning the legal concept of sovereignty over a celestial body, the establishment of clear property rights, equitable resource allocation, the definition and enforcement of human rights in extreme off-world environments, the mechanisms for conflict resolution, and the development of genuinely viable and sustainable financing models remain largely unresolved. These critical issues are often fragmented across diverse national interests, private corporate agendas, and

international legal interpretations, creating a disjunction that undermines the very foundation upon which a truly thriving and enduring Martian outpost is envisioned. This inherent tension between technological capability and socio-political-economic preparedness represents a precarious and potentially perilous condition for what is widely anticipated as humanity's next great leap.

The profound relevance of this problem extends far beyond the immediate technicalities of spaceflight, touching upon critical global challenges and fundamental questions about humanity's future trajectory. Firstly, the imperative for Martian colonization is increasingly framed within the context of existential risk mitigation. As various scholars and futurists argue, establishing a planetary backup or “planet B” for humanity is a crucial insurance policy against catastrophic events on Earth. This rationale is prominently championed by SpaceX founder Elon Musk, who has explicitly stated that his goal for settling Mars is to ensure the survival of mankind. Prominent scientists such as Carl Sagan have suggested that extra-terrestrial settlement may be the only way to prevent the extinction of humanity. Furthermore, authors like Isaac Asimov, John Leslie, Martin Rees, and Nick Bostrom have argued that humanity faces the threat of global disasters, necessitating the construction of “universal shelters” or refuges to ensure the survival of the species and the eventual re-establishment of civilization. This strategy aims to secure a copy of vital materials and human life against threats such as asteroid impacts, supervolcanic eruptions, runaway climate change, global pandemics, or advanced biotechnological threats (Yazıcı & Haqq-Misra, 2022). Brian Patrick Green expands this survivalist argument into the realm of ethics, positing that rapid space settlement is not merely a practical necessity but a moral imperative. Drawing on the philosophy of Hans Jonas, Green argues that because humanity is the only known species capable of complex morality, our extinction would signify the death of morality itself. Therefore, the preservation of the human species must be the “first principle of morality,” overriding other concerns to ensure that moral agency continues to exist in the universe (Green, 2019). However, this backup narrative is not without significant controversy. Ethicists such as Kelly Smith have framed this survivalist drive as a “backup policy” that justifies space settlement as a moral obligation to prevent the total annihilation

of intelligent life. Conversely, critics like Charles Cockell and Linda Billings challenge this view, arguing that the concept of a Plan B is fundamentally flawed. They contend that the environmental services provided by Earth are so complex and irreplaceable that fleeing to a hostile planet like Mars is a false solution, and that the focus should remain on solving terrestrial problems rather than escaping them. This tension between the imperative to survive and the responsibility to preserve our home planet defines the ethical core of the colonization debate (Puumala et al., 2023). The long-term survival of the human species, and with it the continuity of consciousness and morality, is presented as a compelling rationale, lending an unprecedented urgency to space settlement. However, the efficacy of Mars as a true “safehold” is critically dependent on its self-sufficiency and resilience, which in turn hinges on robust political and economic frameworks that can withstand terrestrial instabilities.

Secondly, the emerging new space economy underscores the immediate practical relevance of this study. With private investment flooding the sector and a proliferation of commercial actors, space is rapidly transforming from a state-dominated domain into a vibrant, competitive, and increasingly commercialized frontier. Orlova characterizes this shift as the evolution of a “Business Ecosystem”, where the traditional vertical silos of the space industry are being replaced by a complex, interconnected network of stakeholders ranging from startups to tech giants (Orlova et al., 2020). Gonzalez further defines this as a process of “Astropreneurial Co-creation”, where private entrepreneurs are no longer mere contractors for government agencies but are actively reshaping the economic landscape through innovation and risk-taking, effectively co-creating the value of the orbital economy alongside the state (Gonzalez, 2023).

However, this rapid commercialization introduces novel challenges regarding regulation, liability, intellectual property, and fair competition on an interplanetary scale. The potential for resource extraction on Mars and asteroids, for instance, promises vast economic opportunities, but simultaneously raises complex questions of ownership and equitable distribution. Harris and Wonglimpiyarat argue that the sheer capital magnitude of Mars commercialization requires entirely new “aerospace financing” models that go beyond traditional venture capital, necessitating robust financial architectures that can withstand

long-term return horizons (Harris & Wonglimpiyarat, 2023a). Yet, as Michal warns, the rush to secure these returns risks establishing a system of “Private Governance”, where corporate entities, in the absence of strong international enforcement, begin to write their own rules of engagement (Michal, 2016). This evokes historical concerns over colonial exploitation, suggesting that without innovative and sustainable economic models that move beyond traditional terrestrial frameworks, the governance of extraterrestrial commerce may default to the interests of the financier rather than the benefit of the community.

Thirdly, Martian colonization is deeply embedded in contemporary geopolitical shifts and power struggles. As nations and private entities compete for leadership in this emerging domain, the ability to establish a foothold on Mars becomes a potent symbol of global influence and technological supremacy. Akbar describes this dynamic as a neo-realist scramble for “*terra nullius*”, where the lack of clear sovereignty creates a vacuum that major powers are racing to fill, not merely for scientific prestige but for strategic dominance over the “high boundary” of Earth's orbit and beyond (Akbar et al., 2023). This competitive drive is further complicated by what Dickey and Gleason identify as the erosion of normative behaviour in space; as capabilities proliferate, the restraint that characterized the Cold War era is giving way to a more aggressive posture where commercial and military objectives are increasingly indistinguishable (Dickey & Gleason, 2024). Consequently, this renewed “space race” risks exacerbating existing terrestrial rivalries, potentially leading to unproductive competition over vital resources and strategic locations on Mars, such as water-ice deposits or lava tubes, rather than fostering cooperative endeavours.

The lessons from Earth's past, where exploration often led to exploitation and conflict, are stark warnings that must be heeded. The geopolitical landscape demands robust international cooperation and clear governance to ensure that space remains a domain for peaceful purposes and benefits all of humanity, rather than becoming a new arena for conflict and unilateral assertion of power. Jakhu affirms that the principle of “peaceful purposes”, once the bedrock of space law, is currently under siege by a political narrative that reframes space as a “warfighting domain”, thereby justifying the deployment of dual-use technologies that could destabilize the fragile peace of a future settlement (Jakhu et al., 2020). Hammack

reinforces this concern, noting that the risk of “miscalculation” in such a remote and high-stakes environment is amplified by the lack of open communication channels and shared regulatory frameworks, making the potential for accidental escalation on Mars a distinct possibility (Hammack, 2021). Therefore, avoiding the weaponization of the Red Planet requires not just technological safeguards, but a fundamental recommitment to the multilateral governance structures that have so far prevented conflict in the global commons.

Furthermore, the endeavour compels humanity to confront fundamental ethical and legal dilemmas that challenge our terrestrial norms. The very act of sending humans to Mars, particularly in the context of potentially one-way missions, raises profound questions about the nature of informed consent and the limits of human endurance. Mazur claims that standard bioethical frameworks are insufficient for Mars, as they cannot adequately account for the irreversible physiological and psychological changes settlers will endure, effectively rendering “consent” a moving target as the mission progresses (Mazur et al., 2020). This is compounded by the issue of human rights in extreme isolation; Ferreira posit that without a new application of international human rights instruments specifically tailored to the extraterrestrial context, settlers may find themselves in a “rights vacuum” where the sending entity has total control over their life support, necessitating a legal duty of care that extends far beyond current employment law (Ferreira-Snyman et al., 2019).

Moreover, the potential for indigenous Martian life, even microbial, introduces critical bioethical considerations and the imperative of planetary protection. Lopez challenges the traditional pristine approach, arguing that microbial contamination is inevitable and that we must instead develop “Proactive Inoculation Protocols” to manage the biological collision between Earth and Mars responsibly, rather than pretending it can be avoided (Lopez et al., 2019). However, Puumala warns that this biological interference raises deep ethical questions about our right to irreversibly alter another biosphere, suggesting that the desirability of settlement must be weighed against the intrinsic value of Martian environments (Puumala et al., 2023). Consequently, the current legal vacuum concerning property rights, resource governance, and jurisdiction beyond Earth's orbit is not merely a bureaucratic gap but a moral chasm. It necessitates the development of innovative legal and normative models that can

adapt to these unprecedented circumstances, ensuring that the expansion of the human species does not come at the cost of its universal values.

In light of these escalating stakes, the problem of the underdeveloped political and economic frameworks for Martian colonization becomes acutely relevant. Suppose humanity is to embark on this audacious journey successfully. In that case, it must proactively address these challenges, ensuring that the grand vision of a multi-planetary future is built on a foundation of sustainability, cooperation, and ethical responsibility, rather than becoming another chapter in a history marked by conflict and exploitation.

This thesis seeks to answer the critical question: What are the key political and economic obstacles to establishing a human settlement on Mars, and what strategies can be implemented to overcome these challenges in order to develop a sustainable, cooperative, and long-term framework for Martian colonization?

This inquiry is not merely an academic exercise; it is driven by a deep conviction that the dream of Martian colonization, if pursued responsibly, can offer profound benefits for humanity, from safeguarding our long-term survival against existential threats to expanding our scientific knowledge, inspiring global innovation, and fostering unprecedented international cooperation. However, realizing these transformative benefits necessitates a rigorous, proactive, and critically informed approach to identifying and strategically addressing the formidable political and economic hurdles that currently lie ahead.

2. Political–Economic Foundations and the Definition of Exogeography

2.1 What Is Exogeography? A Critical Definition

To embark on a scholarly inquiry into the human settlement of Mars, it is imperative to establish a robust conceptual foundation that extends beyond conventional terrestrial paradigms. This thesis introduces and critically defines Exogeography as a pivotal analytical lens for understanding humanity's burgeoning presence and activities in extraterrestrial environments. Rooted in the rich tradition of geographical thought, exogeography transcends the Earth-bound confines of traditional geographical inquiry to encompass the complex interplay between human societies and celestial bodies.

At its core, geography is the study of human presence and action within the spaces they inhabit, exploring how societies interact with, shape, and are shaped by their environments. Exogeography applies this fundamental principle to the cosmic realm, examining how our political, economic, and social structures are projected onto, adapted within, and ultimately transformed by new extraterrestrial contexts. As Gianluca Casagrande eloquently articulates the very essence of geography is human presence and action, and thus, “A geography to come: Exogeography” extends this to our ventures beyond Earth (Casagrande, 2021). Casagrande posits that while our planet is indeed “the cradle of intelligence”, humanity cannot eternally live in a cradle, implying a natural, albeit complex, drive towards extraterrestrial expansion. Exogeography, in this light, is not merely the cartography of alien landscapes or the cataloging of extraterrestrial resources; it is, more profoundly, the critical examination of how terrestrial social, economic, and political dynamics are projected onto and subsequently re-articulated within these new cosmic environments.

This critical definition of exogeography inherently acknowledges that outer space is not a political or economic vacuum, but rather an emergent arena where existing terrestrial power dynamics and socio-cultural constructs are actively extended and reconfigured. As many scholars emphasize, studies on outer space, particularly within the social sciences and

humanities, have increasingly drawn inspiration from critical geographical approaches. They argue that “human geographers have begun to re-engage with outer space as an object of their research”, recognizing that, “no space is free from human intent, human desire, and human imagination” (Dunnnett et al., 2019). This perspective is crucial because, Earth and outer space are not discrete domains but are “deeply interconnected by flows of meaning and matter that interrelate through zones of designation such as orbital space” (Hunter & Nelson, 2021).

Therefore, exogeography allows for a nuanced understanding of how our terrestrial anxieties, hopes, economic imperatives, and geopolitical rivalries manifest in, and in turn are shaped by, the pursuit of Martian colonization.

Furthermore, it critically interrogates the language and narratives employed in discussions of space exploration and colonization. Terms such as frontier, conquest, and colonization, while historically evocative of terrestrial expansion, carry profound implications rooted in legacies of colonialism, exploitation, and the imposition of dominant power structures. These terms refer to indigenous persons and exploitation, necessitating a careful consideration of their application to Mars, which currently lacks indigenous populations in the traditional sense (Michal, 2016). Yet, the very act of framing Mars as “*terra nullius*”, a blank slate awaiting human inscription, replicates a problematic historical narrative that often justified past colonial endeavours. Exogeography, therefore, involves deconstructing these narratives to reveal their underlying assumptions and potential consequences for the future of extraterrestrial societies.

Giordano defines exogeography as a direct evolution of classical geopolitics and focuses on the projection of power beyond Earth. For Giordano, the cardinal concept is no longer Mackinder's “Heartland” or Mahan's “sea power”, but the “High Boundary”. The High Boundary is that strategic domain, coinciding with Earth orbit and, by extension, nearby celestial bodies like the Moon and Mars, whose control allows a decisive advantage over the terrestrial activities below. Whoever controls this new “high ground” controls planetary communications, surveillance, and logistics. Martian colonization, in this perspective, ceases to be a purely scientific or survivalist adventure and becomes the ultimate objective in the

competition for the High Boundary (Giordano, 2025b).

Exogeography is ultimately defined as the interdisciplinary study of the spatial dimensions of human activity in outer space and on celestial bodies, critically examining how terrestrial political, economic, and social structures are extended, adapted, and transformed in extraterrestrial environments. It is a lens that compels us to acknowledge that space is not merely a physical expanse but a socially produced and politically contested arena, whose future will be shaped by the very human desires and dynamics that have historically defined our presence on Earth. This critical definition serves as the bedrock for understanding the complex obstacles and the imperative for cooperative, sustainable solutions in the context of Martian colonization.

2.2 Theoretical Relevance of Exogeography within the Political Economy of Space

The theoretical relevance of exogeography within the broader political economy of space cannot be overstated. It provides a crucial framework for dissecting the intricate web of motivations, power dynamics, and economic imperatives that underpin the drive towards Martian colonization. By extending geographical inquiry beyond Earth, exogeography reveals that the exploration and potential settlement of celestial bodies are not detached scientific pursuits but rather deeply embedded extensions of terrestrial political and economic systems. This section elucidates how exogeography, through its critical lens, illuminates the fundamental forces shaping humanity's extraterrestrial future.

Firstly, exogeography exposes the underlying economic imperatives driving space expansionism, particularly within the burgeoning “new space” era. The traditional state-led model of space exploration, often driven by scientific curiosity and national prestige, is increasingly being supplemented, and in some cases, supplanted, by a vibrant commercial sector motivated by profit and market creation. This shift is not arbitrary; it is a direct consequence of global capitalism's inherent drive for accumulation and expansion. Economic

ventures increasingly seek to extend territorial possibilities for resource acquisition and the creation of new commodities and services (Dickens & Ormrod, 2007). Mars, with its confirmed deposits of water ice, various minerals, and potential for energy resources, is envisioned as the next frontier for such fixes (Neukart, 2024). This pursuit of extraterrestrial resources, from Martian regolith for construction to hypothetical helium-3 for fusion energy, is directly linked to terrestrial economic demands and the perceived limitations of Earth's finite resources. Exogeography critically examines how these resource frontiers are opened and how their exploitation might replicate historical patterns of colonial extraction and unequal distribution, potentially exacerbating global wealth disparities rather than alleviating them (Young & Docherty, 2025). Secondly, exogeography is instrumental in dissecting the geopolitical dimensions of space, revealing how outer space serves as an arena for the projection and contestation of power. The renewed “space race” is not merely about technological supremacy; it is fundamentally about asserting global influence, gaining strategic advantages, and shaping the future international order. Nations like the United States, China, and Russia, alongside emerging space powers, view capabilities in space as critical for national security, economic competitiveness, and international prestige (Akbar et al., 2023). The ability to establish a permanent presence on Mars would undoubtedly be a potent symbol of global leadership, akin to historical achievements during previous ages of discovery (Pyne, 2016). Exogeography allows for an analysis of how strategic locations on Mars, such as those offering natural radiation shielding (lava tubes), or rich in water ice and minerals, become contested territories, potentially leading to new forms of “cosmic enclosure” (Klinger, 2021). This theoretical lens helps to understand why states and private entities are willing to invest colossal sums in Martian endeavours, not just for scientific returns, but for the tangible and intangible benefits of geopolitical positioning and power projection.

Thirdly, exogeography sheds light on the evolving nature of governance and regulatory frameworks in the extraterrestrial realm. The existing international space law, notably the 1967 Outer Space Treaty (OST), while establishing principles like the “common heritage of mankind” and prohibiting national appropriation, was drafted during an era dominated by

state-led exploration (Cheney, n.d.). It struggles to adequately address the complexities arising from the increasing involvement of private commercial actors and the prospect of permanent human settlements (Putro, 2020). Exogeography highlights the inherent tension between the OST's foundational principles and the practical need for robust governance on Mars, including the establishment of clear property rights for resources and infrastructure, mechanisms for dispute resolution, and frameworks for criminal and civil law. The critical perspective of exogeography compels us to question whose interests these new governance models will serve and whether they will foster equitable development or merely extend existing terrestrial inequalities into space (Michal, 2016). The debate over whether Martian governance should be an extension of Earth-based national laws, a purely international cooperative model, or an emergent, self-governing system, is a central concern within exogeographical inquiry.

Finally, exogeography provides a framework for understanding the ethical and social implications of humanity's expansion into space. It necessitates a critical examination of the narratives that underpin space colonization, particularly the often-utopian visions that promise a fresh start free from Earth's problems. These narratives, often propagated by “techno-optimism”, can obscure urgent terrestrial issues like climate change and extreme wealth disparities (Young & Docherty, 2025). Exogeography, by contrast, grounds the discussion in the realities of human behavior and societal structures, reminding us that colonizing Mars will inevitably involve projecting our values, our conflicts, and our ethical dilemmas onto a new environment (Puumala et al., 2023). This includes profound questions about planetary protection, the potential impact on hypothetical indigenous Martian life (even microbial), and the human rights of settlers in extreme and isolated conditions (Lim, n.d.).

In essence, the theoretical relevance of exogeography within the political economy of space is its capacity to integrate the physical realities of the extraterrestrial environment with the socio-political and economic forces driving humanity's expansion. It allows for a nuanced understanding of how resource acquisition, geopolitical competition, governance structures, and ethical considerations are inextricably linked, shaping the feasibility, sustainability, and very nature of any future Martian settlement. This interdisciplinary approach is vital for

moving beyond a purely technical understanding of space exploration towards a more comprehensive and critically informed vision of humanity's multi-planetary future.

2.3 Integrated Theoretical Frameworks

To comprehensively address the complexities inherent in establishing a human settlement on Mars, a challenge that transcends singular disciplinary boundaries, this thesis adopts an integrated theoretical framework. This approach enables a holistic analysis of the political, economic, legal, ethical, and social dimensions of Martian exploration and colonization. Rather than treating these domains in isolation, the synthesis of multiple perspectives uncovers the intricate interdependencies that shape the project of settling another planet.

A foundational perspective within this integrated approach is Critical Geopolitics. This framework enables a deconstruction of how celestial bodies like Mars are imagined, represented, and ultimately utilized to serve specific political agendas. Drawing on insights from scholars such as Jason Beery, Critical Geopolitics interrogates the narratives that frame space as a “new frontier”, a “*terra nullius*”, or a “global commons” (Beery, 2016). These discourses do not merely describe outer space; they actively legitimize particular actions, such as resource extraction, militarization, and human settlement, while simultaneously obscuring alternative possibilities or ethical concerns. For example, conceptualizing Mars as a backup planet provides political and ideological justification for vast expenditures and high-risk initiatives, even as it potentially diverts attention from urgent terrestrial issues. Moreover, the symbolic act of establishing a human presence on Mars can be understood as an extension of historical patterns of colonial expansion, signalling a new arena for projecting global power.

Complementing this geopolitical lens is the framework of International Political Economy (IPE), which provides critical tools for analysing the interaction between political authority and economic forces in the emerging domain of space. Highlighting the motivations and mechanisms behind economic activity in outer space, from financing strategies and market

creation to the equitable distribution of benefits. The rise of the “new space economy”, characterized by rapid flows of capital and information, reflects broader transformations in global capitalism as described by Manuel Castells in “The Rise of the Network Society”. Within this context, private corporate interests and state agendas often converge, shaping both policy and technological innovation (Castells, 2010).

Organizational Theory further enriches this analysis by focusing on the behaviour and evolution of the diverse institutions engaged in space exploration. This includes international organizations such as the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) and the International Telecommunication Union (ITU), as well as private entities like SpaceX and Blue Origin. Organizational Theory examines how these actors navigate geopolitical tensions, manage internal bureaucracies, and form partnerships across sectors. It also provides insight into how institutional dynamics influence space governance, from the establishment of regulatory norms to the operationalization of complex missions. Through this lens, the thesis explores how collaboration and competition among these actors might shape the trajectory of human settlement on Mars.

The normative and regulatory dimensions of Martian colonization are addressed through the combined framework of International Space Law and Ethics. International Space Law, especially the 1967 Outer Space Treaty, lays down foundational principles such as the prohibition of national appropriation and the notion of space as the common heritage of humanity. However, these legal instruments face significant challenges considering evolving technological capabilities and commercial ambitions.

By weaving together these distinct yet interrelated theoretical perspectives, this thesis constructs a comprehensive analytical framework capable of grappling with the full spectrum of challenges posed by Martian colonization (Giordano, 2025c). It moves beyond reductionist or purely technical interpretations, framing the endeavour as a deeply political, economic, legal, and ethical undertaking. Such an integrated approach is essential not only for understanding the complexities of establishing a human presence on Mars but also for developing sustainable and just strategies for humanity's potential future as a multi-planetary

species.

2.4 Methodology

This thesis adopts a predominantly qualitative research methodology grounded in a systematic review and thematic synthesis of existing academic literature. This approach is particularly appropriate for investigating the complex political and economic challenges involved in establishing a human settlement on Mars and for formulating interdisciplinary strategies to address them. However, in recognition of the integral role of economic feasibility within this inquiry, the research also incorporates a focused cost-benefit analysis based on secondary quantitative economic data. This mixed-methods element complements the qualitative analysis by providing empirical grounding for discussions of financial viability.

The research design centres on a systematic literature review complemented by thematic synthesis. The interdisciplinary nature of the research question necessitates the integration of diverse theoretical and empirical sources from political science, economics, law, ethics, and organizational studies. The systematic review ensures a comprehensive and methodologically sound selection of materials, thereby laying a robust foundation for subsequent analysis. Thematic synthesis, in turn, facilitates the identification of recurring patterns, conceptual linkages, and salient arguments across the selected literature. This process does not merely summarize prior work but interprets and critically engages with it to generate novel insights.

Data collection involves the meticulous identification and examination of academic articles, policy documents, economic reports, and technical assessments relevant to the political, economic, legal, and ethical dimensions of Mars colonization. The documents are selected on the basis of their scholarly rigour, topical relevance, and contribution to one or more aspects of the research question. Particular attention is given to sources addressing geopolitical dynamics, space law, governance frameworks, ethical considerations, and, crucially for the cost-benefit analysis, economic modelling, cost projections, and resource assessments pertaining to Martian missions and infrastructure.

A structured and iterative approach is employed during data collection and analysis. The analytical phase is structured around three core objectives. First, it identifies and categorises the principal political and economic obstacles to Mars colonization. Secondly, the analysis examined the strategies proposed in the literature to address these challenges.

Third, a comparative analytical lens is employed to evaluate the relevance of terrestrial precedents, most notably the Antarctic Treaty System, to the governance of Mars. These comparisons are instrumental in illuminating potential models for cooperation, as well as cautionary lessons regarding territorial competition and resource exploitation. The historical analysis of colonial endeavours further deepened the critique, enabling the identification of structural patterns that may be reproduced in space if not carefully mitigated.

The cost-benefit analysis employed in this study serves not as a mechanism for producing definitive financial estimates, a task rendered unfeasible by inherent technological uncertainties, but rather as a heuristic tool to evaluate the economic feasibility and long-term sustainability of competing governance models. Consequently, the analysis focuses on development and infrastructure costs; while private actors such as SpaceX are actively reducing launch costs, this study evaluates the substantial expenditures required for habitat construction, whether subterranean or surface-based, as well as the development of closed-loop life support systems and energy generation technologies.

In turn, the sustainability of these expenditures is contingent upon the financing models employed. This thesis analyses the viability of purely state-run programs, analogous to the Apollo Program, alongside public-private partnerships (PPPs) and entirely private initiatives, identifying that the latter require clear business models capable of generating returns. Finally, the evaluation of benefits extends beyond monetary calculations to include economic returns derived from the exploitation of in-situ resources (ISRU), such as water ice for propellant or deuterium, alongside the potential value of intellectual property and technological patents. These tangible returns are weighed against the geopolitical value of "strategic advantage" and scientific progress, as well as the existential, albeit unquantifiable, benefit of establishing humanity as a multiplanetary species to ensure long-term survival.

The final stage of the analysis entails a critical assessment of all proposed strategies in terms of their feasibility, sustainability, and alignment with principles of justice and cooperation.

Through this primarily qualitative yet methodologically flexible approach, this thesis aspires to contribute meaningfully to academic and policy debates on Mars colonization. The integration of cost-benefit analysis ensures that economic dimensions are rigorously evaluated, while the overarching thematic synthesis maintains coherence with qualitative standards.

3. Strategic Geography and Governance of Mars

3.1 Why Geography Matters: Earth–Mars Parallels in Space Geopolitics

The projection of human political and economic activity onto Mars cannot be understood solely through the lens of technological feasibility; it fundamentally requires a geographical analysis of power. Just as terrestrial geopolitics has historically been dictated by the control of physical terrain, land masses, maritime chokepoints, and resource-rich hinterlands, the governance of Mars will be strictly defined by its specific exogeographic characteristics (Casagrande, 2021). History demonstrates that the morphology of a territory often dictates the political structures that emerge upon it. The colonization of the Americas, the partition of Africa, and the Great Game in Central Asia were all driven by the quest to secure strategic depth and resource extraction zones. As Galindez argues, this process of "planetary urbanization" extends the logic of imperial capitalism beyond the atmosphere, threatening to reproduce terrestrial inequalities in the cosmos (Galindez, 2023). This logic is likely to be replicated in the solar system (Puumala et al., 2023). However, the transition from Earth to Mars introduces a vertical dimension to this competition that classical geopolitics could only theorize. Mars is not merely a distant colony; within the High Boundary framework proposed by Giordano, it represents the ultimate strategic vantage point. Control over the Martian surface and its orbital space offers not only access to distinct resources but potentially a dominant position within the cislunar and interplanetary economy, effectively extending the "high ground" advantage from Earth orbit to deep space (Giordano, 2025b).

The parallel with Earth lies most deeply in the relationship between geography and survival, a connection that shapes the political "hydraulic civilizations" of antiquity as much as modern petro-states. Just as early river-valley civilizations in Mesopotamia and the Nile were constrained by the availability of water and arable land, a Martian settlement will be defined by the unforgiving constraints of its physical environment. The "tyranny of distance", the immense communication lag (ranging from 3 to 22 minutes) and the logistical hurdle of the Hohmann transfer window, creates a unique geopolitical condition (Mazur et al., 2020). To

understand this, we must apply Manuel Castells' theory of the “Space of Flows”. Castells argues that modern power relies on real-time connection; however, the physics of Mars disconnects it from Earth's real-time network, forcing the colony to exist in a separate temporal reality (Castells, 2010). Unlike terrestrial colonies of the 19th century, which could be patrolled by imperial navies within weeks or months, a Martian settlement possesses a natural insulation that encourages autonomy. This geographic isolation creates an inevitable tension between the terrestrial powers attempting to project authority via the High Boundary and the local imperatives of the settlers, whose survival depends on adapting to the specific geography of the Red Planet.

This tension between surface autonomy and terrestrial projection could be managed, through the control of specific exogeographic features that function as the “keys” to the planetary system. While the vastness of space suggests an environment of limitless maneuver, the energetic realities of orbital mechanics impose strict pathways for travel and logistics, creating celestial chokepoints analogous to terrestrial bottlenecks like the Strait of Malacca or the Suez Canal. In the Martian theatre, the moon Phobos might serve as the ultimate manifestation of this strategic logic. Orbiting at a remarkably close distance of approximately 6,000 kilometres from the surface, Phobos represents the “High Boundary” in its most tangible form: a physical anchor in the gravity well that dominates the terrain below.

The geopolitical significance of Phobos transcends its status as a satellite; it acts as a logistical fulcrum that mitigates the very “tyranny of distance” that otherwise isolates the Martian surface. As detailed by Samokhin, the moon’s negligible gravity allows it to serve as an optimal staging ground where spacecraft can land and launch with minimal fuel expenditure, avoiding the prohibitive energetic costs of entering and exiting Mars' deep gravity well for every mission. Furthermore, a base on Phobos allows for the tele-operation of robotic assets on the Martian surface with near-zero signal latency, effectively bypassing the communication lag with Earth and establishing a “forward operating base” capable of directing surface industrialization without immediate human exposure to the planet’s harsh environment (Samokhin et al., 2023).

Consequently, political sovereignty over Phobos equates to the power of a gatekeeper. Just as a fortress overlooking a harbour dictates the terms of trade, a presence on Phobos grants the capability to monitor, interdict, or facilitate all traffic entering the Martian sphere. This dynamic suggests that the struggle for Martian independence or terrestrial control will likely centre not on the red sands of the surface, but on the occupation of this orbital high ground. Securing this moon allows a dominant actor to enforce a regulatory or military regime over the entire planetary system, validating the exogeographic maxim that security on the surface is contingent upon dominance in the High Boundary.

Beyond the orbital gateways, the internal geography of the Martian surface dictates a fragmentation of sovereignty that challenges the notion of a unified planetary government. This geopolitical landscape is defined by a stark “hemispheric dichotomy”, a physical division between the smooth, flat northern lowlands and the rugged, impact-scarred highlands of the south. In exogeographic terms, this dichotomy creates two distinct theatres of operation, mirroring the classical terrestrial division between a resource-rich “Heartland” and a defensive “Rimland”. The northern mid-latitudes, specifically regions like Arcadia Planitia and Deuteronilus Mensae, emerge as the “Resource Heartland” of the Martian sphere. These areas represent a critical “Middle Ground” where the requirements for solar energy (sunlight) and industrial feedstock (accessible subsurface water ice) overlap. Control over this territory confers not just survival but economic dominance; the ability to extract and process water ice into hydrogen-oxygen propellant transforms these plains into the primary fuelling stations of the solar system, effectively breaking the logistical tether to Earth.

However, while the northern plains offer economic superiority through ease of mobility and resource extraction, the rugged terrain of the Tharsis volcanic region and the southern highlands offers “strategic depth”. On Earth, nations seek strategic depth, distance and physical barriers, to absorb attacks and secure critical infrastructure (Mukundan et al., 2023). On Mars, this depth can be found in the massive lava tubes located on the flanks of volcanoes like Pavonis Mons. These subterranean caverns, protected by tens of meters of basaltic rock, provide natural fortification against the two greatest threats of the Martian theatre: lethal

cosmic radiation and micrometeoroid bombardment. Unlike the exposed domes of the northern plains, which are vulnerable to structural failure and external attack, settlements within lava tubes possess a natural resilience that makes them ideal for secure command centres or long-term habitation (Neukart, 2024).

This geographical divergence suggests that early Martian governance will likely not be homogenous but will instead cluster around these competing strategic imperatives. Commercial actors driven by efficiency and export potential will gravitate toward the resource heartlands of the north to maximize production capabilities. In contrast, state actors prioritizing security and survivability may seek the fortified depth of the volcanic provinces. This dynamic creates the potential for a bifurcated geopolitical order, where the "industrial north" controls the flow of fuel and trade, while the "fortified south" retains the capacity for military endurance and command continuity. Consequently, the struggle for planetary influence will likely manifest as a competition to balance these two imperatives: securing the vulnerable economic engines of the plains while maintaining the secure redoubts of the highlands.

The competition for geography extends into the invisible but equally vital territory of the electromagnetic spectrum. While often conceptualized as an infinite resource, the spectrum available for deep-space communication is finite and governed by strict physical laws, making it a contested terrain in its own right. The ability to maintain high-bandwidth communication between Mars and Earth, essential for the tele-operation of infrastructure, the transmission of scientific data, and the psychological well-being of settlers, is contingent upon securing specific frequency allocations, particularly in the X-band (7,125–8,400 MHz) and Ka-band. In the terrestrial context, spectrum is sovereign territory; nations vehemently protect their airwaves to ensure security and economic stability. In the Martian theatre, this "invisible geography" becomes the lifeline of the settlement.

However, the projected congestion of the Martian sphere by competing state and commercial actors threatens to saturate this limited resource. As noted by Audrey Allison, the uncoordinated proliferation of satellite constellations and surface transmitters creates a high

risk of frequency interference, which in the harsh environment of space constitutes a direct threat to life-support systems and navigation (Allison, 2024). Just as a blockade of a physical port constitutes an act of war, the denial or degradation of these communication channels, whether accidental or intentional, represents a violation of sovereignty that can cripple a colony's operations. Consequently, the governance of Mars must extend beyond the physical surface to include a rigid management regime for the electromagnetic spectrum, transforming it from an open common into a regulated "High Boundary" where access is strictly controlled to prevent the tragedy of the commons. This contest for the invisible lanes of communication mirrors terrestrial conflicts over cyber-sovereignty and airspace, reinforcing the thesis that human expansion into space exports terrestrial political rivalries rather than transcending them.

3.2 Strategic Exogeographic Elements

Phobos' operational utility extends into the domain of surveillance and temporal hegemony. In a governance context, Phobos functions as a planetary Panopticon. Orbiting at an altitude of only 6,000 kilometres, closer than any major moon in the solar system, it completes a revolution every 7 hours and 39 minutes. This rapid orbital period allows a facility on Phobos to scan the Martian surface multiple times per sol, providing near-continuous observation of settlement activities below. Unlike satellites in high geostationary orbits which have resolution limitations, a monitoring station on Phobos possesses the physical capacity to track individual vehicle movements and infrastructure development across the entire colonized hemisphere (Giordano, 2025b). For a governing authority, this eliminates the "fog of war", ensuring that no surface settlement can secretly develop military capabilities or violate resource extraction treaties without immediate detection from above.

Beyond surveillance, Phobos offers a decisive temporal advantage that dictates the hierarchy of command. The fundamental constraint of Martian governance, as stated previously, is the light-lag, which renders direct administration from Earth impossible during crises. However, a command centre on Phobos operates with a signal latency of approximately 30 to 50

milliseconds relative to the surface. While this real-time capability allows operators on the moon to tele-operate robotic swarms and life-support machinery on Mars with human-level dexterity, in political terms it means that it creates a sovereignty gradient where the entity stationed on Phobos holds executive power because it is the only actor capable of immediate reaction (Samokhin et al., 2023). Earth-based governments are relegated to a legislative or advisory role, always lagging behind events, while the “Governor of Phobos” possesses the functional capacity to override surface systems instantly. This might dictate that the administrative capital of Mars will likely not be a city on the plains but a station on the moon.

Finally, the defence of this asset requires a shift in security doctrine from territorial defence to vital asset protection. Because Phobos sits at the top of the Martian gravity well, it possesses a massive kinetic energy advantage, meaning objects dropped from Phobos strike the surface with devastating force while surface-to-orbit defences must fight gravity to retaliate. This physics dictates a doctrine of absolute denial, meaning a surface colony cannot allow a hostile or rival power to occupy Phobos, as doing so would place the colony under a permanent siege (Dickey & Gleason, 2024). Consequently, the governance of Phobos will likely involve strict exclusion zones, what Bateman terms “keep-out zones” around critical infrastructure, where no unauthorized approach is permitted, creating a militarized buffer zone in orbit long before borders are drawn on the sand (Bateman, 2024).

However, the domination of the orbital gateway represents only the external shell of Martian sovereignty. While Phobos dictates who enters or exits the system, it cannot determine the internal viability of the settlement itself. The true theatre of political legitimacy and economic production lies at the bottom of the gravity well, where the abstract advantages of orbital mechanics are replaced by the concrete necessities of hydrology and geology. A “Gatekeeper State” on the moon may hold the keys to the planet, but it is the surface geography that provides the house. Therefore, the focus of exogeographic analysis must descend from the High Boundary to the regolith, where the governance of the colony will not be defined by the vacuum of space, but by the uneven distribution of the resources required to sustain life. It is here that the unified control of the orbital panopticon gives way to a fractured reality, defined by a planetary geography that splits the world into two distinct and competing

theatres.

The “fractured reality” of Martian geopolitics is physically inscribed upon the planet through the hemispheric dichotomy, a stark geological division that splits Mars into two opposing theatres. While the southern highlands represent a rugged, defensive terrain, the Northern Lowlands, specifically regions such as “Arcadia Planitia” and “Utopia Planitia”, emerge as the indisputable “Resource Heartland” of the planetary economy. This region constitutes what Neukart identifies as the “Middle Ground”: a strategic band of latitude where the requirements for solar energy (sufficient sunlight) and industrial feedstock (accessible subsurface water ice) overlap (Neukart, 2024). Unlike the poles, where extreme cold prohibits permanent habitation, or the equator, where ice is unstable or buried too deep, the northern mid-latitudes offer the only zone where a settlement can achieve self-sufficiency. Consequently, the first “capital cities” of Mars will almost certainly be founded here, dictated not by aesthetic choice but by the hard constraints of hydrological availability (Puumala et al., 2023).

The political significance of this ice cannot be overstated; on Mars, water is not merely a biological necessity but the currency of sovereignty. As detailed by Mukundan, the extraction of water ice is the prerequisite for In-Situ Resource Utilization (ISRU), specifically the electrolysis of water into hydrogen and oxygen (Mukundan et al., 2023). This process provides the breathable atmosphere for the population and, crucially, the rocket propellant required to return to Earth. Control over the northern ice fields therefore equates to “energy sovereignty”. A colony that controls its own fuel source breaks the logistical tether to Earth, transitioning from a dependent outpost to an autonomous political actor (Mazur et al., 2020). This transforms the geography of the Jezero Crater and surrounding basins from mere geological curiosities into the “oil fields” of the space economy, where the physical control of extraction infrastructure will determine the balance of power between Earth-based corporations and local settler governments (Galindez, 2023).

However, the imperative to manage this scarce resource creates a severe risk of political authoritarianism. As Charles Cockell warns in his analysis of “Interplanetary Liberty”, the

control of air and water creates the conditions for a “lethal tyranny” unknown on Earth. In terrestrial history, “hydraulic civilizations” like ancient Mesopotamia developed rigid bureaucracies to manage irrigation; on Mars, this logic is amplified because the state must guarantee the molecular composition of the atmosphere itself. If a single entity controls the “tap” of the Northern Plains, it holds absolute power over the biological existence of the citizenry. This suggests that the Resource Heartland will be governed by strict operational protocols rather than democratic consensus, where dissent against resource allocation is treated as a threat to collective survival (Cockell, 2022).

The concentration of critical infrastructure in the open plains creates a profound security dilemma. While the Northern Lowlands are optimal for resource extraction, they lack strategic depth. The flat, smooth terrain offers no natural protection against the primary threats of the Martian theatre: lethal cosmic radiation and orbital bombardment. As noted by security scholars like Bateman, infrastructure that is essential to the survival of a state becomes the primary target in any conflict (Bateman, 2024). The electrolysis plants and habitation domes of the north are “soft targets”, fragile structures sitting exposed under a thin atmosphere. This vulnerability necessitates a heavy security presence, effectively turning the industrial zones of the north into militarized garrisons, and driving the strategic need for secure command centres elsewhere (Neukart, 2024).

However, while the Northern Plains provide the economic lifeblood of the settlement through resource extraction, they fail to provide its security. The very features that make the “Middle Ground” accessible, flat terrain, thin atmosphere, and proximity to surface ice, also render it defenceless against the primary hostilities of the Martian theatre. Surface infrastructure in these regions remains perpetually vulnerable to lethal cosmic radiation, micrometeoroid bombardment, and the strategic threat of orbital interdiction. A state that exists solely on the surface is a fragile glass house, economically productive but militarily indefensible. Consequently, the imperative for political continuity and long-term survival necessitates a geographic shift away from the exposed industrial zones. To find true sovereignty, defined by the ability of a state to endure catastrophe, the focus of exogeography must turn from the resource-rich plains to the natural fortresses buried beneath the crust.

Here, massive lava tubes offer the only environment on Mars capable of guaranteeing the long-term survival of a governing body against the planet's hostile baseline. According to research presented by Pozzobon, the specific gravity environment of Mars allows these volcanic conduits to form on a scale vastly superior to those on Earth. While terrestrial tubes rarely exceed thirty meters in width, Martian lava tubes show evidence of reaching 250 meters in width (Europlanet, 2017). This scale fundamentally alters their geopolitical function, transforming them from mere geological curiosities into viable spaces for urban-scale habitation. As the researchers note, such dimensions are sufficient to house entire historic city centres, suggesting that the “underground” is not a marginal space for emergency shelter but the primary candidate for a permanent, secure outpost. Because Martian lava tubes are large enough to house entire cities, they allow “the government” to centralize the population in one secure location, making policing and administration easier than if people were scattered in small surface domes.

The governance implications of this geography are defined by the concept of passive security. On the surface, the state must expend massive energy resources to actively protect citizens from cosmic radiation and micrometeorites, a “soft constraint” that Puumala identifies as a major barrier to feasible settlement (Puumala et al., 2023). However, the basaltic roof of a lava tube provides a natural shield that neutralizes these threats without maintenance. As Martin and Benaroya demonstrate, these subterranean environments offer a stable thermal equilibrium and protection from radiation that would otherwise require prohibitive amounts of manufactured shielding on the surface. From a cost-benefit perspective, this makes the lava tubes the most economically viable location for critical infrastructure. By utilizing this ready-made geology, a Martian administration can bypass the immense capital costs of constructing radiation-proof domes, effectively allowing the planet itself to subsidize the colony's security (Martin & Benaroya, 2023).

This geographical advantage aligns with the ethical imperative of survival. As Brian Patrick Green argues, if the primary moral obligation of a space settlement is to prevent human extinction, then the preservation of the species takes precedence over other concerns (Green, 2019). Consequently, the “Bunker State” mentality becomes a moral requirement rather than

just a strategic choice. By relocating high-value assets, such as data servers, genetic banks, and executive leadership, into these deep fissures, the Martian state ensures that the mechanism of governance can survive even if the surface population faces a catastrophic solar event or orbital bombardment. Furthermore, the obscurity of these formations adds a layer of strategic secrecy. As Carrer notes, conventional remote sensing instruments cannot detect the full extent of these tubes from orbit; they require specialized low-frequency radar to be mapped (Europlanet, 2017). This natural stealth grants a governing authority an advantage, allowing for the concealment of military or political assets from external surveillance.

However, this vertical separation of infrastructure risks calcifying into a vertical separation of social class, driven for example by the costly technology that will be radiation shielding. Constructing safe habitats on the surface requires the manufacturing of thick, resource-intensive domes, making “surface safety” a prohibitively expensive commodity. In contrast, the natural basaltic roof of a lava tube provides superior protection for free. Consequently, these geological safe havens will likely be prioritized for high-value assets and command personnel to minimize insurance liabilities, forcing the bulk of the manual workforce to inhabit the higher-risk, cheaper infrastructure of the surface, effectively mapping the colony’s geological profile onto its socioeconomic hierarch. Drawing on Galindez’s critique of “planetary urbanization”, the usage of lava tubes risks creating a physical architecture of inequality (Galindez, 2023). If the safe subterranean zones are limited in volume, they will likely be prioritized for essential personnel and high-value assets, leaving the bulk of the workforce to inhabit the riskier, radiation-exposed domes of the extraction zones. This echoes the concerns raised by Mazur regarding the potential for centralized tyranny in space settlements, where the strict control of safe habitats reinforces a rigid hierarchy (Mazur et al., 2020). The lava tubes represent the “High Keep” of Martian exogeography, a territory massive enough to govern from, safe enough to ensure survival, and hidden enough to defend, but one that threatens to physically stratify the population into a protected elite and an exposed periphery.

These three distinct exogeographic elements, the orbital gateway of Phobos, the resource

heartland of the Northern Plains, and the subterranean fortresses of the volcanic provinces, constitute the “Grand Chessboard” of Martian governance. Power on the Red Planet will not be derived solely from ideology or law, but from the physical control of these specific assets. A stable planetary government must effectively integrate these disjointed theatres: it must secure the High Boundary to control access, regulate the hydraulic economy of the plains to ensure sustenance, and maintain the secure depths of the lava tubes to guarantee political continuity. This fragmented geography suggests that early Martian sovereignty will not be a homogenous blanket of authority, but a complex, multi-layered system where the struggle for dominance is fought over the specific chokepoints of orbit, ice, and shelter.

3.3 Governance Model for an early outpost

The transition from a transient presence to a permanent foothold on Mars necessitates a fundamental reevaluation of political authority. Unlike established terrestrial states or the eventual “cities” envisioned by futurists, an early outpost occupies a liminal geopolitical space: it is neither a fully militarized expedition nor a functioning civil society. In this nascent phase, the mechanisms of governance are strictly dictated by the “hard constraints” of the environment, where the margin for error is non-existent and the survival of the collective supersedes individual liberties. Consequently, the governance of this period should not be understood as a static constitution, but as an evolutionary progression driven by the tension between operational safety and human necessity. This section traces that evolution: beginning with the Scientific Consensus Model, which functions as the technocratic baseline for survival; transitioning to a Behavioural Model derived from analogue missions to manage long-term social cohesion; and finally confronting the Corporate Sovereign, the overarching legal container that constrains this entire developmental process.

The initial human presence on Mars will not function as a “settlement” in the municipal sense, but rather as a High-Reliability Organization (HRO) analogous to a nuclear submarine or the International Space Station (ISS). In this early phase, the primary objective is not the expansion of civil liberties but the maintenance of life-critical systems in a uniquely lethal

environment. Consequently, the governance model will be defined by a “Technocratic Baseline” where authority is derived strictly from technical competence rather than democratic mandate (Giordano, 2025c). As Mazur argues, the unforgiving nature of the Martian environment imposes “hard constraints” on social organization; because a single error in life-support management or airlock protocols can result in total mission failure, decision-making regarding resource allocation and safety must be centralized and expert-driven rather than subjected to a popular vote (Mazur et al., 2020). In this context, the citizen is primarily a crew member, and their rights are subordinated to the operational necessities of the mission, creating a legal status more akin to a soldier on deployment than a civilian in a democracy (Puumala et al., 2023).

However, to characterize this governance merely as “autocratic” ignores the complexity of modern high-stakes operations. A more sophisticated framework for this early phase is what Eytan Tepper describes as “Polycentric Governance.” Drawing on the institutional analysis of Elinor Ostrom, Tepper argues that governance in complex, high-risk systems is most effective when it is distributed across multiple, overlapping centres of authority rather than concentrated in a single leader (Tepper, 2019). In the specific context of a Martian outpost, this manifests as a system of “Distributed Expertise”, where the hierarchy is fluid and context dependent. While a “Mission Commander” may hold executive authority over the timeline and external communications, specific domains, such as life support, geology, or medical health, are governed autonomously by their respective specialists. For example, during a routine day, the Commander leads; however, during a medical emergency or a radiation storm, the Chief Medical Officer or the Lead Engineer assumes *de facto* command, and their decisions structurally outrank those of the political leadership (Roberts, 1990). This aligns with the “Deference to Expertise” principle found in HRO theory, which dictates that in a crisis, authority must migrate to the person with the most relevant knowledge, regardless of their official rank (Karl E. Weick & Kathleen M. Sutcliffe, 2007).

This structure relies on “Scientific Consensus” as its primary legislative mechanism. Unlike a democracy where the majority rules, or a corporation where the shareholder directs, an early outpost operates on the principle of peer review applied to governance. Decisions

regarding exploration targets, water rationing, or risk assessment are debated until a technical consensus is reached among the department heads. This model mirrors the current governance of the International Space Station (ISS), where operations are guided by a “Matrix Structure” of international partners and technical directorates rather than a single sovereign (Paravano et al., 2023). In this matrix, authority is functional rather than territorial; a decision about the oxygen scrubbers is made by the environmental control group, not by a general vote of the inhabitants. This ensures that the governance system remains agile and data-driven, prioritizing the “hard constraints” of physics over social preferences (Martin & Benaroya, 2023).

Yet, while efficient for survival, this model inherently lacks mechanisms for political recourse. As Cockell warns, a system based purely on resource control and technical efficiency creates the apparatus for “interplanetary tyranny” if applied indefinitely. In a technocracy, there is no separation of powers; the entity that manages the air supply also writes the laws regarding its use. This “Scientific Consensus” model assumes rational actors working toward a shared scientific goal, but it provides no framework for resolving non-technical disputes, such as resource theft, interpersonal conflict, or conscientious objection. This suggests that while Polycentric Technocracy is the necessary operating system for the physical survival of the outpost, it remains an incomplete governance model for a human society, creating a freedom gap that widens as the mission duration increases.

The transition from a dependent outpost to an autonomous society begins with the functional collapse of the “Ground Control” model. In the early history of spaceflight, the governance of a mission was strictly heteronomous; every minute of an astronaut's schedule was dictated by a centralized authority on Earth, a structure that remains efficient only as long as communication is instantaneous. However, empirical data derived from high-fidelity analog simulations demonstrates that this command hierarchy degrades rapidly under the specific constraints of the Martian environment. Research conducted by Saint-Guillain during Mars analogue campaigns reveals that as communication delays increase, the “bottleneck of authority” created by remote scheduling leads to operational paralysis; when crews are forced to wait for ground validation to resolve minor scheduling conflicts or equipment failures,

mission efficiency drops precipitously (Saint-Guillain et al., 2023). Similarly, Osinski noted during the CanMars sample return analogue that rigid adherence to Earth-based decision cycles resulted in significant idle time and lost scientific opportunities (Osinski et al., 2019). Consequently, the outpost is forced by the physics of the environment to undergo a Sociological Pivot: the transfer of executive power from the remote Mission Control to the local crew. This shift represents a fundamental political evolution from a “mission” logic, where the sovereign is distant and the crew is instrumental, to a “community” logic, where the sovereign is present and the crew becomes autonomous.

Once this autonomy is established, the mechanism of governance must necessarily evolve from explicit regulation to implicit social management. Without the constant, panoptic oversight of Earth, the “military” discipline characteristic of the Technocratic Baseline proves insufficient for maintaining long-term cohesion. Findings from the HI-SEAS missions (Hawaii Space Exploration Analog and Simulation) provide critical sociological evidence for this shift; Heinicke documents how crews surviving isolation for durations of up to twelve months spontaneously replaced rigid rulebooks with internal “Group-Living Habits” (Heinicke et al., 2021). These unwritten social contracts, manifesting as communal meals, shared leisure time, and the voluntary division of maintenance chores, functioned as a “soft constitution”, regulating behaviour more effectively than orders from a designated Commander. The narrative evidence from the Crew Montes mission at MDRS further validates this, describing the crew’s survival strategy not as obedience to a hierarchy, but as a collective “war” against the hostile environment, where roles became fluid and leadership rotated based on the immediate needs of the habitat (Nascente Schmitt, 2025). This suggests that the primary threat to the outpost is not technical failure, but social fragmentation; therefore, the governance model must pivot to prioritize the curation of these norms, transforming a group of strangers into a functional, self-regulating polity.

However, this self-regulating society is fragile and maintaining it requires a governance structure that actively manages information flow and cognitive stress. Data from the AMADEE-20 mission highlights that poor communication quality, specifically a lack of clarity in objectives, directly correlates with increased frustration and mental effort, which in

turn degrades team performance. Hagemann argues that without a shared mental model, the “information flow” between the crew and their support systems breaks down, leading to a cognitive overload that threatens the mission's stability (Hagemann et al., 2023). Furthermore, Lalla’s analysis of remote science operations during AMADEE-18 emphasizes that this friction is exacerbated when the scientific goals are not aligned with the operational realities of the crew (Lalla et al., 2021). In this context, governance becomes a matter of “cognitive ergonomics”; the administration must ensure that the crew is not just physically safe, but socially and mentally synchronized. This validates the need for a specialized “Behavioural Model” of governance, where conflict resolution and stress mitigation are treated as essential infrastructure, akin to air recycling or water filtration, requiring the presence of specialized “Governance Specialists” within the crew to manage the human variable.

This behavioural management relies on a new and potentially invasive form of surveillance, which establishes a paradigm of “Therapeutic Sovereignty”. To prevent the catastrophic social breakdown predicted by analogue studies, the outpost’s governance system must monitor the physiological and psychological state of its citizens with unprecedented intimacy. The 2025 Flashline Mars Arctic Research Station mission pioneered the use of voice inflection analysis to monitor stress levels in real-time, effectively dissolving the boundary between private emotion and public safety data (The Mars Society, 2025). Derobertmeasure further demonstrates the necessity of continuous physiological monitoring, such as analysing heart rate variability and cortisol levels, to detect stress before it escalates into interpersonal conflict (Derobertmeasure et al., 2025). While Klicker notes that such “safety shadows” are essential for survival in extreme environments, they effectively eliminate the concept of privacy (Klicker et al., 2023). In the Behavioural Model, the state knows not only where the citizen is, but how they feel. This creates a “total institution” where every deviation in mood is flagged as a safety risk, suggesting that while the Sociological Pivot liberates the crew from Earth’s control, it subjects them to a localized bio-political control that may be difficult to dismantle as the settlement grows.

In practice, the shift to behavioral governance fundamentally alters the decision-making

architecture of the outpost, transforming the crew from passive executors into active legislators of their own survival. The traditional vertical loop, where instructions descend from Earth, is replaced by a horizontal consensus model within the habitat. Saint-Guillain describes this as a transition to astronaut self-scheduling, where the crew receives high-level objectives but retains full sovereignty over the execution timeline (Saint-Guillain et al., 2023). This effectively transforms daily briefings from status reports into legislative sessions where resource allocation, such as who utilizes the rover, who claims bandwidth, or who conducts maintenance, is negotiated based on the immediate workload and fatigue levels of the members rather than a pre-set flight plan. This agility is not merely an operational preference but a governance necessity; as Osinski noted, the ability to deviate from the plan in real-time allows the local sovereign to exploit scientific opportunities that a distant authority would miss due to time-delay latency, effectively establishing the crew as the primary political agent on the planet (Osinski et al., 2019).

Consequently, the legal framework of the outpost initially evolves from a rigid code of military conduct into a flexible system of social norms. In long-duration isolation, formal mission rules imposed from the outside are often less effective than group-living habits developed from the inside (Heinicke et al., 2021). For instance, mandatory communal activities emerge not just as nutritional events, but as the primary judicial forums where interpersonal grievances are aired and defused before they escalate into mutiny. These rituals constitute a soft constitution, regulating behaviour through peer pressure and shared expectation rather than the threat of punitive action. In this environment, a violation of the cleaning rota is treated with the same gravity as a technical error, because in a confined ecosystem, the failure to contribute to the collective maintenance is viewed as a breach of the social contract that underpins the crew's survival (Heinicke et al., 2021). Relying solely on informal habits, however, is insufficient for a permanent settlement; as the population expands or the mission duration extends indefinitely, these unwritten norms must inevitably crystallize into a formal body of law. Informal social pressure works in small, cohesive groups, but it lacks the precision and predictability required for a complex community. Therefore, the governance model must progress to a stage of codification, where the “soft

constitution” of habits is transcribed into written community statutes. This new legal code differs significantly from the initial “Mission Rules” provided by the space agency; while Mission Rules focus on the safety of the hardware, Community Statutes focus on the rights of the inhabitants. This transition marks the birth of a true Martian polity, where the settlers draft binding regulations regarding privacy, personal property usage, and grievance resolution, effectively moving the source of law from the employment contract to the consent of the governed (Mazur et al., 2020).

The enforcement of these new laws moves away from punitive measures toward a model of restorative justice and therapeutic intervention. In a small, interdependence-heavy population, placing a skilled specialist in confinement or removing them from duty is counter-productive to the survival of the group. Instead, justice becomes a function of health and stability. Derobertmeasure highlights the role of continuous biometric and acoustic monitoring not as evidence for prosecution, but as triggers for early intervention (Derobertmeasure et al., 2025). If a crew member violates a community statute regarding work hours or resource consumption, the response is likely to be mediated through the Governance Specialist, who utilizes physiological data to address the underlying stress or fatigue rather than administering punishment. Thus, the outpost functions as a therapeutic state, where the primary goal of the law is to rehabilitate the human component of the machine to optimal functionality, ensuring that the body of law serves the biological continuity of the settlement (Klicker et al., 2023).

The internal evolution toward a therapeutic, self-governing polity operates within a rigid external container defined by the legal and physical ownership of the habitat. While the crew may perceive themselves as citizens drafting community statutes based on the consent of the governed, they remain legally situated as employees within a post-bureaucratic corporate structure, a reality that fundamentally alters the nature of their sovereignty. Unlike the exploration of the 20th century, which was characterized by state-led expeditions where the government retained architectural knowledge and operational control, the colonization of Mars is increasingly defined by a model of public-private partnership where the state is merely a client. Roy’s analysis of NASA’s governance during the Space Shuttle era

demonstrates that the state previously acted as the system architect, filtering knowledge and dictating design specifications to private contractors who were merely implementers. In that era, the government maintained a hierarchy of knowledge that ensured public accountability; the contractor built the hardware, but the state owned the mission, the data, and the ultimate authority over the crew's safety and conduct (Roy, 2025).

In stark contrast, the contemporary architecture of Mars colonization disrupts this hierarchy, replacing the state-centric bureaucracy with a vertically integrated corporate model. Le Coze argues that New Space actors, specifically SpaceX, have dismantled the traditional state bureaucracy in favor of a “post-bureaucratic” structure where the private corporation, not the space agency, holds the technical and operational reins. Through vertical integration, the corporation controls every aspect of the mission, from the manufacturing of the rocket engines to the code running the life support systems, effectively privatizing the “architectural knowledge” that was once the domain of the public sector. This shifts the role of the government from an overseer to a customer; NASA does not run the Starship program, it simply purchases seats on it. Consequently, the crew is not deployed by a sovereign nation but is rather leased to a corporate service provider, creating a dynamic where the ultimate authority over their environment, their return journey, and their survival rests not with a constitution, but with a board of directors operating under commercial imperatives (Le Coze, 2024).

This architectural monopoly translates directly into a precarious operational dependency for the state. Recent data from the 2024–2025 launch window reveals the extent of this lock-in: SpaceX conducted approximately 52% of all global launches and nearly 95% of all U.S. launches in 2024, effectively becoming the sole gateway to orbit for the American government (Harrison, 2025). With the retirement of the Atlas V and delays in the Vulcan and Ariane 6 programs, NASA has found itself in a position of “single-source” vulnerability, relying entirely on the Falcon 9 and Dragon systems for crew transport to the ISS. This is not merely a matter of market share but of sovereignty; as noted in the Payload Space analysis, the U.S. government has transitioned from a position where it owned the means of transport to one where it is a distressed buyer in a seller's market (Kuhr, 2025). In a Mars scenario, this

power imbalance would be absolute. The corporation would control not just the ride, but the life-support infrastructure itself, creating a dynamic where the state's ability to intervene in the outpost's affairs is contingent upon the continued goodwill and financial viability of the private operator.

The geopolitical risks of this dependency are already visible in the militarization of the Starlink network during the Ukraine conflict. The Finabel report and recent analysis by the European Parliament highlight that while Starlink provided critical communication resilience for Ukraine, its dual-use nature allowed the corporate operator to unilaterally restrict service in contested zones, effectively making the company a strategic arbiter in a sovereign conflict (Radin et al., 2025; Sacchi, 2024). This has driven the European Union to accelerate its own IRIS² programme, explicitly citing the need for “strategic autonomy” to avoid reliance on non-EU private actors for secure government communications (Renew Europe, 2023). For a Mars colony, this precedent is chilling: it suggests that a “Corporate Sovereign” could leverage its control over the outpost's communication and supply lines to bypass democratic oversight, enforcing its own “Terms of Service” as the supreme law of the settlement. Thus, the “Behavioural Autonomy” of the crew is structurally fragile, existing only as long as it does not conflict with the strategic or commercial objectives of the infrastructure owner.

The legal consequence of this operational dependency is the emergence of a “Company Town” dynamic, where the corporation functions simultaneously as the employer, the landlord, and the state. Aaditya Vikram Sharma warns that in the absence of a robust international legal framework, these settlements risk devolving into zones of unchecked corporate sovereignty, where the civil liberties of the crew are defined not by a constitution, but by the Terms of Service of the habitat provider (Aaditya Vikram Sharma, 2025). In a traditional company town on Earth, a worker who is fired can simply leave the premises; on Mars, expulsion is a death sentence, meaning that the corporation's power to terminate employment is functionally equivalent to the power of life and death. This creates a coercive environment where the “Behavioural Autonomy” described in the previous section becomes performative rather than substantive. The crew may be permitted to self-schedule their day or resolve minor interpersonal conflicts, but they are structurally prohibited from challenging

the strategic objectives of the mission or the safety margins dictated by the board of directors. This structure facilitates a form of “anticipatory authoritarianism”, where the extreme constraints of the environment are used to justify a pre-emptive surrender of rights before the rocket even launches, establishing a governance model based on total compliance rather than consent (Young & Docherty, 2025).

This surrender of rights is exacerbated by the fact that current international space law is ill-equipped to protect individuals within a private settlement. The Outer Space Treaty (OST) and major human rights instruments were designed to regulate the behavior of States, not private corporations operating extraterritorially (Ferreira-Snyman et al., 2019). While the OST posits that the launching State retains jurisdiction and control over the space object, it offers no mechanism for a crew member to seek redress against a private operator for violations of privacy, speech, or labor rights that occur forty million miles from Earth. Lim argues that this creates a “jurisdictional gap” where the corporation can effectively operate in a legal gray zone; the United States government may theoretically have oversight, but if the government is dependent on that same corporation for its own access to space (as established in the previous paragraphs), its political will to enforce strict human rights standards may be compromised (Lim, n.d.). Consequently, the Company Town becomes a legal silo where the proprietary rights of the hardware owner supersede the human rights of the inhabitants, creating a scenario where the oxygen you breathe is a licensed service rather than a fundamental right.

Ultimately, this tension between the *human* need for a social contract and the *corporate* reality of the private contract renders the “Corporate Sovereign” model unsustainable for a permanent civilization. Dickey and Gleason suggest that as these activities expand beyond simple exploration into settlement, the lack of established norms for private actors will lead to inevitable conflict, not just between the crew and the company, but between the company and the State (Dickey & Gleason, 2024). The “Sociological Pivot” drives the crew toward self-governance and the formation of a political identity, but the “Corporate Container” confines them to the status of assets within a balance sheet. If the outpost is to evolve from a managed facility into a true polity, it must eventually transcend the corporate framework that

built it. This necessitates a search for a legal precedent that can separate operational control from sovereign authority, a governance model that can accommodate extreme interdependence without enforcing total surveillance.

Fortunately, this legal experiment has already been conducted on Earth. In 1959, facing a similar crisis of overlapping territorial claims and the need for scientific survival in a hostile environment, the nations of the world agreed to suspend the very concept of sovereignty in Antarctica. The Antarctic Treaty System (ATS) successfully froze the geopolitical competition that threatened to militarize the southern continent, creating instead a “reserve devoted to peace and science” where governance is based on consensus rather than coercion (British Antarctic Survey, 2018). The “Antarctic Exception”, where the suspension of sovereignty allowed for the emergence of a unique international community, provides the only viable blueprint for a Martian settlement that wishes to escape the trap of the Company Town (Young & Docherty, 2025). Therefore, to understand the future of Martian governance, we must examine the history of the Antarctic Treaty, not merely as a conservation agreement, but as a radical political innovation that decoupled the right to rule from the right to own territory.

3.4 Case Study: The Antarctic Treaty System

The governance model that eventually stabilized Antarctica did not emerge from a vacuum of idealistic cooperation, but rather from a geopolitical “balance of terror” that threatened to extend the Cold War into the southern hemisphere. By the mid-20th century, the Antarctic continent was effectively the subject of a slow-motion colonial scramble, distinct from the resource-driven conquests of the Americas but equally rooted in the projection of national power. Caldwell notes that while early exploration was driven by imperial expansion and resource extraction, the Antarctic dynamic was complicated by the presence of seven claimant nations, Argentina, Australia, Chile, France, New Zealand, Norway, and the United Kingdom, whose pie-shaped territorial assertions frequently overlapped and conflicted (Caldwell, n.d.). This tension was particularly acute between the United Kingdom,

Argentina, and Chile, whose competing claims over the Antarctic Peninsula created a volatile diplomatic standoff. Superimposed on this regional friction was the broader strategic rivalry between the United States and the Soviet Union, neither of whom made territorial claims but both of whom reserved the right to do so, adopting a posture of “strategic denial” to prevent the other from gaining a foothold. As Berkman argues, the risk was not merely diplomatic; the potential for military bases or nuclear testing sites at the bottom of the world presented a security dilemma that required a radical departure from traditional statecraft to resolve (Paul Arthur Berkman et al., 2011).

The catalyst for de-escalation arrived not through political channels, but through the scientific community, which proposed the International Geophysical Year (IGY) of 1957-1958 as a mechanism to bypass the deadlock of sovereignty. This event operated on a “gentleman’s agreement” that allowed scientists to establish bases and conduct research anywhere on the continent, regardless of political boundaries or territorial claims. Scully observes that the IGY effectively decoupled scientific activity from political assertion, creating a temporary functional cooperation that prioritized the gathering of data over the planting of flags (Scully, 2011). This “science diplomacy” provided a neutral language through which the superpowers could engage, transforming the frozen continent from a theatre of potential conflict into a shared laboratory. The success of the IGY demonstrated that operational cooperation was possible even in the absence of a resolution on the underlying question of ownership, proving that rival nations could coexist in a “terra communis” if the stakes of sovereignty were removed from the immediate equation.

Recognizing the fleeting nature of this scientific truce, the United States, under the Eisenhower administration, sought to institutionalize the IGY’s cooperative spirit before the Cold War tensions could reassert themselves. In 1958, President Eisenhower invited the twelve nations active in the IGY to Washington to negotiate a permanent regime, explicitly framing the initiative as a measure to prevent the continent from becoming “an object of international discord”. Berkman highlights that Eisenhower’s approach was fundamentally pragmatic; the goal was to freeze the geopolitical status quo to ensure that the southern polar region would not become a new front in the nuclear arms race (Paul Arthur Berkman et al.,

2011). This diplomatic manoeuvre required a delicate balancing act, as it asked claimant nations to voluntarily suspend the enforcement of their sovereignty without formally renouncing their rights. The resulting negotiations were driven by the realization that an unmanaged scramble for Antarctica would ultimately serve no nation's security interests, compelling the participants to accept a governance model based on collective stewardship rather than exclusive dominion.

The culmination of these efforts was the signing of the Antarctic Treaty in 1959, which legally enshrined the continent as a zone dedicated exclusively to “peaceful purposes.” The preamble of the Treaty explicitly recognizes that it is in the interest of all mankind that Antarctica shall not become the scene of international discord, a sentiment that marked a definitive break from the colonial logic of previous centuries (THE ANTARCTIC TREATY, 1959). Caldwell contrasts this with the Treaty of Tordesillas or the colonial partitioning of Africa, noting that for the first time in history, a vast territory was managed not for the economic benefit of the conqueror, but for the scientific benefit of humanity (Caldwell, n.d.). By prohibiting any measures of a military nature, such as the establishment of military bases and fortifications, the Treaty successfully inoculated the continent against the geopolitical viruses plaguing the rest of the globe. This historical pivot, from strategic rivalry to scientific preservation, establishes the critical precedent for Mars: it proves that when the environmental and political costs of conflict are sufficiently high, competing powers can be persuaded to suspend their sovereignty in favour of a survival-based cooperative regime.

The core mechanism of the Antarctic Treaty System, and the singular mechanism that has prevented conflict on the continent for over six decades, is Article IV. This provision does not resolve the question of sovereignty but rather suspends it, creating a legal time-out that allows competing national interests to coexist without surrendering their fundamental claims. The text of the article explicitly states that “no acts or activities taking place while the present Treaty is in force shall constitute a basis for asserting, supporting or denying a claim to territorial sovereignty in Antarctica or create any rights of sovereignty in Antarctica” (THE ANTARCTIC TREATY, 1959). Triggs describes this as a masterstroke of legal creativity, a “legal fiction” that effectively separates the status of the land from the actions performed

upon it. By rendering all activities legally invisible for the purposes of territorial acquisition, the Treaty allows nations to build bases, conduct inspections, and deploy personnel without any of these actions hardening into a permanent title. This suspension is what makes the “Antarctic Exception” possible; it is a diplomatic device that acknowledges the reality of conflicting claims while simultaneously rendering them irrelevant to the daily governance of the continent (Paul Arthur Berkman et al., 2011).

This legal innovation relies on what scholars describe as a bifocal approach, a deliberate ambiguity that permits two contradictory legal realities to exist simultaneously. For claimant states like Chile or Australia, the regulations of the Treaty are interpreted as the exercise of their own sovereign rights over their national territory; they view their compliance as a voluntary limitation of their own jurisdiction. Conversely, for non-claimant states like the United States or Russia, who recognize no territorial claims on the continent, the same regulations are viewed as international mandates applied to a “global commons” or *terra nullius* (as previously mentioned). Berkman notes that this duality was essential for bringing the superpowers to the table during the Cold War; it allowed the United States to maintain its “open door” policy, reserving the right to access any part of the continent, without forcing claimant nations to suffer the humiliation of formally renouncing their territories (Paul Arthur Berkman et al., 2011). This “agreement to disagree” effectively removed the toxic element of prestige from the equation, allowing the governance of Antarctica to proceed based on functional cooperation rather than the rigid enforcement of borders.

Currently, corporate attempts to declare independence, such as the “free planet” clause in SpaceX's Starlink terms of service, are legally void under Article II of the Outer Space Treaty, which prohibits national appropriation by any means. Caldwell argues that because corporations are subject to the jurisdiction of their launching state, they cannot unilaterally sever the legal tether to Earth or declare a new sovereignty (Caldwell, n.d.). However, a “Martian Article IV” could adapt the Antarctic precedent to private entities: it would prevent a corporation's construction of life-support infrastructure from constituting a claim to ownership of the planetary surface. While Haqq-Misra posits that true economic freedom might eventually require Mars to become a fully sovereign peer to Earth, disconnected from

terrestrial law, the Antarctic model offers a more immediate and realistic transitional framework (Haqq-Misra, 2025). By treating the settlement as a facility operating within a “suspended” jurisdiction, the legal focus shifts from who owns the land to who has the right to access and use it, preventing the settlement from becoming a private fiefdom while protecting the investment of the operator.

The adoption of such a legal fiction is the only viable path to ensure that a Martian settlement evolves into a polity rather than a prison. Without a mechanism like Article IV to neutralize the link between occupation and ownership, every module landed on Mars becomes a de facto territorial claim, inevitably importing terrestrial power struggles onto a new world. Triggs emphasizes that the success of the Antarctic Treaty lies in its flexibility, its ability to evolve from a security pact into a comprehensive environmental regime without ever resolving the underlying sovereignty dispute (Paul Arthur Berkman et al., 2011). For Mars, this implies that the question of “who owns the planet” does not need to be answered before settlement begins; it simply needs to be suspended. This suspension allows for the organic development of local governance structures protected by an international umbrella that guarantees civil rights and open access, ensuring that the human expansion into space remains a collective endeavour rather than a corporate conquest.

The durability of the Antarctic Treaty System lies in its ability to evolve from a static security pact into a dynamic environmental regime. Initially, the Treaty was predicated on “strategic denial”, a Cold War mechanism designed to deny the Soviet Union or the United States exclusive control over the continent. However, as the geopolitical thaw of the 1980s reduced the threat of militarization, the focus of governance shifted toward the contentious issue of resource extraction. Joyner observes that the system faced a critical existential crisis with the negotiation of the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA) in 1988, a framework that would have permitted regulated mining. The collapse of this agreement in the face of global public opposition marked a paradigm shift: rather than managing exploitation, the Consultative Parties chose to prohibit it entirely. This decision was codified in the 1991 Protocol on Environmental Protection (the Madrid Protocol), which designated Antarctica as a “natural reserve, devoted to peace and science” and imposed an

indefinite ban on all mineral resource activities (Paul Arthur Berkman et al., 2011). This transformation demonstrates that international governance can successfully prioritize preservation over profit, provided there is sufficient political will to elevate the intrinsic value of a territory above its extractive potential.

While the Madrid Protocol offers a powerful legal precedent, the biological reality of Mars presents a more complex challenge than the frozen desert of Antarctica. The Antarctic environmental ethos is based on keeping the continent uncontaminated and minimizing human impact to preserve its value as a reference laboratory. On Mars, the stakes are exponentially higher due to the potential for indigenous microbial life, yet the ability to maintain an uncontaminated environment is paradoxically lower. The strict contamination avoidance policies currently championed by planetary protection agencies are ultimately futile in the face of human colonization; relying on a “zero-contamination” standard is technically impossible once humans, who are essentially walking ecosystems, land on the surface (Lopez et al., 2019). Consequently, applying the Antarctic model to Mars requires a shift from avoidance to management. The goal cannot simply be to keep Mars sterile, as the Madrid Protocol attempts for Antarctica, but rather to implement “Proactive Inoculation Protocols” that manage the inevitable biological collision between Earth and Mars responsibly. This suggests that while the legal framework of the Madrid Protocol (a ban on commercial exploitation) is essential, its operational standards must be adapted to acknowledge that human presence will irreversibly alter the Martian biosphere.

Despite these biological complications, the legal core of the Madrid Protocol remains the most viable model for preventing the “Company Town” scenario on Mars. If the settlement is legally categorized as a “Scientific Preserve” rather than a commercial colony, the economic incentives of the operators change fundamentally. This Antarctic Exception is the only framework that can decouple the necessary activity of in-situ resource utilization (extracting ice for water and oxygen) from the commercial logic of export and profit (Young & Docherty, 2025). In this model, SpaceX or any other operator is permitted to harvest Martian resources solely for the purpose of sustaining life and supporting scientific inquiry, just as Antarctic bases melt ice for water, but is legally prohibited from commodifying those

resources for trade. This distinction is critical: it allows for the operational survival of the outpost without validating a corporate claim to the planet's wealth, ensuring that the oxygen settlers breathe remains a shared resource of the community rather than a licensed product of the corporation.

The concept of the “Antarctic Exception” represents a viable geopolitical firewall against the fragmentation of the Martian frontier into a chaotic patchwork of corporate domains. We are currently facing a “closing window” of opportunity similar to 1959; just as the IGY preempted the militarization of the poles, immediate legal intervention will be required to prevent the chaos of conflicting claims on Mars. The Antarctic model should not merely be considered as a treaty, but as the deliberate construction of a “global nature”, a political choice to designate a territory as shared heritage rather than *terra nullius* ripe for conquest (Beery, 2016). Without this designation, the vacuum of governance will inevitably be filled by the “privatization of outer space”, where commercial entities like SpaceX assume state-like functions without state-like accountability (Sorrentino Lando, 2019). This risk is not hypothetical; Radin highlights how the Starlink precedent in the Ukraine conflict demonstrated the fragility of relying on commercial actors for essential infrastructure without a binding regulatory framework, a vulnerability that would be existential in the lethal environment of Mars (Radin et al., 2025). Therefore, the application of the Antarctic Exception is not a matter of idealism, but of hard security. It is the necessary mechanism to prevent the Red Planet from becoming a unregulated zone of corporate sovereignty.

Operationally, this exception functions by decoupling the management of life-support systems from the ownership of the planetary surface, effectively neutralizing the threat that the “Company Town” might pose. By designating the settlement as a “planetary trust” or *res communis*, the legal framework ensures that the crew's fundamental rights are guaranteed by international treaty rather than the terms of service of a private corporation (Caldwell, n.d.). A supranational approach such as this one is critical for the protection of human rights in space, as it prevents the jurisdictional gap where a private operator might otherwise supersede national labor or civil liberty laws (Ferreira-Snyman et al., 2019). This structure allows for the economic freedom proposed by Haqq-Misra, permitting the in-situ use of resources for

survival and local development, while legally blocking the commodification of those resources for export or territorial leverage (Haqq-Misra, 2025). This type of suspended sovereignty might provide the protective bubble required for the Sociological Pivot to occur; by removing the pressure of territorial defence and profit maximization, the Antarctic Exception creates the space for a new Martian society to evolve based on the functional necessities of survival rather than the imported hierarchies of Earth.

4. Economy, Geography, and Sustainability

4.1 Cost–Benefit Analysis

The methodological framework for a Martian cost–benefit analysis must move beyond the narrow confines of terrestrial fiscal cycles to adopt a complexity-based systems innovation model (Harris & Wonglimpiyarat, 2023b). In this paradigm, the evaluation of a settlement mission is not measured by immediate profitability but through a multi-century perspective centred on species survival and technological advancement. Because the aerospace industry has not yet achieved a state of full commercialization for deep-space colonization, cost projections function as heuristic tools rather than definitive financial estimates (Harris & Wonglimpiyarat, 2023a). This approach is necessitated by a condition of deep uncertainty, where the long-term monetary stability of a Martian settlement may eventually require sovereign economic structures, such as full reserve banking and localized capital ownership, to prevent the extraction of wealth by terrestrial financial systems (Haqq-Misra, 2025). By framing the CBA as a strategic rather than a purely accounting exercise, the analysis bridges the gap between the immense technical expenditures required and the existential imperatives of a multiplanetary presence (Bushnell, 2021).

The quantification of tangible expenditures for a Martian mission begins with the recognition of its unprecedented fiscal scale, which is estimated to be significantly higher than any previous human spaceflight endeavours. Historical analysis by NASA researchers suggests that the first human mission to Mars could cost approximately half a trillion dollars, a figure that remains consistent across various independent cost-estimating models. To provide terrestrial context, this investment is expected to be two to three times the cost of the Apollo program, the Space Shuttle, or the International Space Station (ISS), and potentially as much as all three programs combined (Jones, 2016). A substantial portion of these costs is driven by the life-cycle requirements of life support systems, which alone are projected to exceed two billion dollars for the initial mission. These estimates rely on mass-cost estimating factors derived from decades of orbital experience, highlighting that even before the first

launch, the financial burden of hardware development and sustainment represents a barrier of immense capital magnitude (Harris & Wonglimpiyarat, 2023a).

The technical architecture required to support such a mission is currently being refined through the NASA Moon to Mars strategy, which utilizes lunar operations as a necessary proving ground for Martian transit. The 2025 Architecture Update emphasizes the development of evolvable lunar infrastructure, including nuclear power systems and utility rovers, which are essential for testing the durability of systems intended for use on the Martian surface (NASA, 2025). According to the Revision C of the Architecture Definition Document, the human-to-Mars segment involves complex sub-architectures for data systems, robotics, and logistics that must handle cargo repositioning of assets greater than six metric tons (NASA, n.d.). However, the NASA Office of Inspector General (OIG) has provided a critical reality check to these projections, noting that the total investment for the precursor Artemis program is projected to reach 93 billion dollars through 2025 (NASA OFFICE OF INSPECTOR GENERAL, 2025). Furthermore, the OIG identifies a staggering production and operations cost of 4.1 billion dollars per launch for the SLS and Orion system, a figure that challenges the long-term fiscal sustainability of state-led models.

Despite these high initial barriers in the public sector, recent technological advancements in reusability and manufacturing are fundamentally shifting the feasibility of deep-space missions toward a commercial efficiency model. The introduction of reusable heavy-lift rockets, along with advances in automation and additive manufacturing, is rapidly opening deep space beyond geostationary orbit to potential commercialization (Bushnell, 2021). These innovations have transformed Martian colonization from an extremely difficult prospect to one that is increasingly feasible with regard to radiation protection, safety, and overall mission cost. In contrast to the multi-billion dollar costs of state-led launches, the private sector has proposed dramatically lower entry points, with early estimates suggesting a ticket price of approximately 500,000 dollars for individual colonists (Michal, 2016). Achieving these cost reductions requires a longer-than-usual business outlook, typically extending a decade or more, which remains a challenge for traditional private investment cycles. The integration of closed business cases is essential for this transition, as the shift

from government-funded exploration to a commercialized ecosystem depends on the ability of private entities to demonstrate consistent reductions in space access costs (Bushnell, 2021).

The shift toward public-private partnerships as a means to distribute these costs introduces a complex economic landscape characterized by both opportunity and systemic risk. While the U.S. government seeks to buy down risk and encourage private investment to maintain leadership in space diplomacy, the transition from government-led stations to commercial stations remains highly speculative. Policymakers face the challenge of minding the gap to ensure that the retirement of current infrastructure does not lead to a disruption in space science or supply chains. This reliance on commercial providers creates a potential single-source vulnerability, where the failure of a private contractor could jeopardize the entire logistical architecture of a Martian mission (Stover & Bukley, 2024). Furthermore, the financing mechanisms for such large-scale endeavours are diversifying, with models exploring the use of crowdfunding and initial coin offerings as supplements to traditional funding, though these remain in early stages of development. Ultimately, the economic landscape of Martian infrastructure is defined by a tension between the need for state-level stability and the drive for commercial innovation that seeks to lower the barriers to entry for the final frontier (Harris & Wonglimpiyarat, 2023a).

The integration of in-situ resource utilization (ISRU) represents the most significant shift in the economic equation of Martian colonization, transitioning the mission from an extractive Earth-reliant model to a self-sustaining planetary presence (NASA, 2025). The ability to extract water ice from the Martian subsurface and process it into liquid oxygen and methane propellant is identified as a critical requirement for closing the business case of long-term settlement. By utilizing the Martian atmosphere and surface materials to produce consumables and fuel, mission architectures can fundamentally break the costly logistical tether to Earth that has historically limited the duration and scope of space exploration (Knappenberger, n.d.). This technological capability effectively functions as a natural subsidy, where the Martian environment provides the raw materials necessary for survival and return transit, thereby reducing the total mass that must be launched from Earth's gravity

well (Levchenko et al., 2019). The 2025 NASA Architecture Update specifically identifies ISRU as a primary sub-architecture that must be matured through lunar testing before it can be reliably deployed to support human life on the Red Planet (NASA, n.d.).

The economic impact of ISRU is best quantified through the reduction of the Initial Mass in Low Earth Orbit (IMLEO), which is the primary driver of launch costs (Jones, 2016). Standard economic models for Martian exploration demonstrate that transporting the propellant required for a return journey from Earth's surface to Mars is prohibitively expensive, as every kilogram of fuel delivered to the Martian surface requires several kilograms of fuel to be expended during transit (Knappenberger, n.d.). By producing this propellant locally, the mission mass can be reduced by hundreds of metric tons, leading to savings that scale exponentially with the size of the colony. These cost-mitigation strategies are essential because traditional mass-cost estimating factors, based on the ISS experience, suggest that a purely Earth-supplied mission would reach fiscal limits long before achieving permanent occupancy. Advances in automated processing and chemical synthesis on the Martian surface therefore would allow for a more aggressive expansion of infrastructure than would be possible under a traditional expendable architecture (Bushnell, 2021).

The strategic influence of Martian geography becomes a primary determinant of economic viability, as the location of a settlement must be optimized for access to these vital resource heartlands (NASA, 2025). According to the Architecture Definition Document, the repositioning of large exploration assets and the transport of cargo to the surface are increasingly dependent on the proximity to water-rich regions, such as the northern mid-latitudes (NASA, n.d.). Control over these geographic chokepoints dictates the financial sustainability of a settlement, as those who command the areas with the highest concentration of accessible ice will possess a significant competitive advantage in propellant production and life support costs. This geographic reality necessitates a sophisticated logistics strategy that accounts for the varying costs of extraction across different Martian terrains, from the relatively accessible polar regions to the strategically valuable but technically challenging lava tubes. Consequently, the exogeography of Mars is not merely a physical backdrop but a dynamic economic factor that determines which settlements can achieve fiscal autonomy

(Levchenko et al., 2019).

The transition from merely getting to Mars to staying there depends on a planetary political economy that manages these resources for the socio-ecological reproduction of the community. While the technical feasibility of ISRU would improve due to reductions in space access costs, the ethical and legal management of these resources will remain a point of contention (Bushnell, 2021). There is a significant risk that a rush to secure resource-rich geography could lead to private governance structures where corporate entities monopolize essential life-support resources under a consumption-based model (Michal, 2016). To avoid the pitfalls of a company-town dynamic, the economic framework must prioritize the common heritage of these resources, ensuring that the natural subsidies provided by the Martian environment serve the survival of the global majority rather than the accumulation strategies of private capital (Tansel & Tilley, 2024). Sustaining a human presence beyond the initial exploration phase therefore requires an economic model that balances the high capital costs of infrastructure with a cooperative regime for resource distribution, ensuring that the risks of economic collapse are mitigated through shared sustainability (Haqq-Misra, 2025).

The cost-benefit analysis also addresses the intangible and existential benefits of Martian colonization, which often elude traditional monetary valuation yet form the core of the ideological justification for the massive capital outlays required. Central to this is what has been termed an anticipatory regime of multiplanetary life, a framework where the future potential of a Martian civilization is mobilized to legitimize present-day economic and political actions. This regime operates by casting the establishment of an off-world outpost not merely as a scientific endeavour but as a necessary survival strategy for the human species. By framing Mars as a horizon of hope and a solution to the perceived limits of Earth, private and state actors can generate significant public and financial support that transcends typical market logic (Young & Docherty, 2025). This form of intangible value is predicated on the belief that the long-term existence of humanity depends on becoming multiplanetary, thereby turning an existential insurance policy into a potent driver of investment that justifies the high costs of initial infrastructure (Levchenko et al., 2019).

The narrative of terrestrial ruin plays a pivotal role in this economic justification, positioning Martian colonization as a moral imperative in the face of ecological or civilizational collapse on Earth. This backup planet discourse effectively commodifies the concept of human survival, allowing space-faring entities to attract capital by presenting themselves as the guardians of the species' future (Michal, 2016). Such a narrative often relies on a form of techno-optimism that suggests technological solutions developed for the Martian environment, such as advanced closed-loop recycling and automated manufacturing, can eventually provide terrestrial spinoffs that benefit the home planet (Bushnell, 2021). However, this intangible benefit is inherently speculative and carries the risk of devaluing the necessary efforts to sustain the Earth's own biosphere by suggesting that an exit strategy is both feasible and preferable. The cost-benefit analysis must therefore weigh the inspirational and existential value of a multiplanetary future against the potential for this narrative to be used as a tool for the enclosure of the atmospheric and planetary commons (Tansel & Tilley, 2024).

A significant existential risk identified in the critical literature is the emergence of private governance structures that could replicate or exacerbate the exclusionary and extractive dynamics of terrestrial history. The historical precedent of company towns and chartered companies provides a cautionary tale for the Martian context, where a private entity could exercise total control over the means of survival through its ownership of essential infrastructure. Under such a model, the consuming of Mars through colonization would prioritize profit maximization and corporate sovereignty over the civil liberties and well-being of the inhabitants. This risk is amplified by the fact that the initial colonists would be entirely dependent on corporate-owned systems for air, water, and protection from radiation. If the economic structure of the settlement is designed as a closed corporate ecosystem, the socio-ecological reproduction of the community becomes secondary to the accumulation strategies of the parent company. This creates a fragile economic landscape where the risk of social and economic collapse is high if the corporate benefactor fails or if the colonial workforce remains trapped in a state of permanent indebtedness (Levchenko et al., 2019).

To mitigate these risks and ensure the long-term sustainability of the mission, the economic

framework must prioritize the socio-ecological reproduction of the community from the outset. This requires a transition toward a planetary political economy that serves the global majority and ensures that the wealth generated through capital ownership and labour is equitably distributed within the settlement. Proposed models for economic freedom on Mars suggest that stability can be maintained through full reserve banking and localized currency systems that prevent the extraction of wealth by fractional reserve Earth currencies (Haqq-Misra, 2025). By diffusing the ownership of capital among all citizens, the colony can foster a resilient society where every individual has a stake in the survival and prosperity of the settlement, transforming it into a planetary trust rather than a commercial asset (Tansel & Tilley, 2024). The most valuable return on investment is the creation of a cooperative society that preserves the common heritage of humanity while providing a new template for human flourishing beyond the limits of terrestrial constraints (Michal, 2016).

4.2 Financing Models

The transformation of aerospace financing for Martian colonization marks a definitive transition from the centralized, state-funded models of the Cold War to a complex, networked ecosystem of public and private co-creation (NASA, 2025). The conceptual foundation for Martian financing is rooted in the rise of the network society, where the “space of flows” facilitates the almost instantaneous exchange of capital and information between terrestrial and extra-orbital actors (Castells, 2010). This environment has enabled the emergence of a fifth-generation innovation model, which emphasizes systems integration and networking over the linear, hierarchical research structures of the past (Harris & Wonglimpiyarat, 2023a). In this paradigm, Martian colonization is no longer an isolated government project but a collaborative endeavour involving a division of labour between public agencies, private firms, and international consortia. The economic viability of the mission depends on the ability of these networks to manage the extreme capital intensity and long-term return horizons inherent in deep-space logistics, ensuring that knowledge and value are developed iteratively across multi-decade schedules (Roy, 2025).

This networked approach is essential for identifying and closing the “business case” gaps that have historically prevented large-scale space commercialization (Pyne, 2016). Unlike traditional aerospace projects, Martian colonization requires an innovative financing logic that accounts for high uncertainty and the absence of immediate terrestrial markets (Harris & Wonglimpiyarat, 2023b). By leveraging the synergies of astropreneurial co-creation, stakeholders can build a competitive commercial frontier where the risks of hardware development are shared across a diverse investment pool (NASA, 2025). This shift reflects a broader global trend where the privatization of space activities allows for a more flexible and resilient financial architecture, one that is less vulnerable to the political fluctuations of national budgets (Stover & Bukley, 2024). Consequently, the success of the mission is tied to the strength of these inter-organizational networks and their capacity to maintain long-term funding consistency in an environment of high operational risk.

However, the transition to a networked model also introduces new complexities regarding the governance of knowledge and the distribution of financial rewards. As public agencies like NASA engage more deeply with private actors, the traditional boundaries of state-led innovation become blurred, necessitating a careful management of intellectual property and national interest. The governance of these public-private partnerships must ensure that the knowledge developed in anticipation of a Martian program remains a shared resource rather than a corporate secret (Roy, 2025). The network society model warns that as the extra-orbital economy grows, the risk of disintegration increases if the social and economic benefits of colonization are captured by a few dominant nodes (Castells, 2010). Therefore, the foundational phase of Martian financing must balance the efficiency of private capital with the ethical requirement to preserve the mission as a stable, transparent, and international project (Putro, 2020).

The contemporary state has evolved from being the sole operator of space missions to a strategic “anchor customer” that buys down technical and financial risks to encourage private entry into the sector. According to the Centre for Space Policy and Strategy, the US government utilizes public-private partnerships to transition from government-owned infrastructure to commercial services, a move designed to lower long-term sustainment costs

while maintaining strategic leadership. By providing guaranteed contracts for cargo and crew transport, as seen in the Artemis and Commercial Crew programs, the state creates a predictable revenue stream that allows private firms to secure venture capital and achieve economies of scale (Harris & Wonglimpiyarat, 2023a). This “risk-mitigation” logic is essential for the precursor missions to Mars, as it ensures that the initial logistical architecture is grounded in a stable, state-backed financial framework (NASA OFFICE OF INSPECTOR GENERAL, 2025).

However, the financial reality of state-led precursor programs highlights the immense fiscal challenges ahead. The NASA Office of Inspector General (OIG) reports that the total investment for the Artemis program is projected to reach 93 billion dollars by 2025, with an operational cost of 4.1 billion dollars per launch for the SLS and Orion system. These figures represent a massive capital hurdle that challenges the long-term sustainability of state budgets, especially when compared to the aggressive cost-reduction targets of the private sector (Tepper, 2019). The “Mind the Gap” challenge identified by space policy analysts emphasizes that any delay in the transition to commercial stations or lunar logistics could lead to a disruption in the entire supply chain, jeopardizing the economic foundation of a future Martian mission (Stover & Bukley, 2024; Tansel & Tilley, 2024). To prevent this, the state must navigate a delicate balance between subsidizing innovation and avoiding the creation of single-source vulnerabilities where the failure of one private contractor could compromise the national space architecture.

Furthermore, the state's role as a financier is increasingly intertwined with the pursuit of prestige and security on the global stage. National space policies, such as those of the US and China, treat the colonization of Mars as an arena for demonstrating technological superiority and securing strategic assets (Sorrentino Lando, 2019). This geopolitical motivation ensures a baseline of funding that is independent of commercial profit, yet it also risks militarizing the economic landscape (Sacchi, 2024). The state must therefore function as a regulator that ensures commercial activities on Mars comply with international law while simultaneously acting as the primary funder of the high-risk, low-profit research necessary for long-term survival. Ultimately, the state provides the legal and financial scaffolding that allows the

market to function in deep space, ensuring that the “initial mass” of capital required for Mars is delivered through a robust and accountable public framework (Putro, 2020).

The second tier of Martian financing is driven by the astropreneurial model, which leverages speculative capital and a distinctive logic of “anticipatory governance” (Harris & Wonglimpiyarat, 2023a). Private entities, most notably SpaceX, have successfully attracted billions in venture capital by framing the colonization of Mars as an existential necessity and a “backup planet” for humanity. This anticipatory regime uses the future potential of a multi-planetary civilization to legitimize current financial behaviours, allowing companies to secure investment that far exceeds their current terrestrial revenue (Tepper, 2019). By selling the vision of a Martian city, astropreneurs can bypass traditional market scepticism and access the massive capital reserves of the global financial elite. As of late 2025, venture capital into the space sector remains high, specifically targeting firms that demonstrate iterative technical progress and the potential for disruptive cost-savings in launch and habitat construction.

This speculative model is built on the pursuit of technology S-curves, where a rapid reduction in the cost-per-kilogram of launch is expected to open up new, massive markets in orbit and beyond. Astropreneurs operate with a much longer return-on-investment horizon than typical venture-backed startups, often extending their business cases to ten or twenty years (Pyne, 2016). The financial viability of this model relies on the assumption that once the barriers to space access are lowered, a “gold rush” of extra-orbital commercial activity will follow, providing the profits necessary to sustain the Martian colony. However, the dominance of a few large players like SpaceX creates a single-source dependency that can stifle competition. This creates a tension between the innovative speed of a private monopoly and the systemic stability required for a multi-planetary economy.

The risks associated with this astropreneurial speculation are significant, as they tie the fate of the mission to the individual successes and public perceptions of a few visionary leaders (Tansel & Tilley, 2024). If a high-profile mission fails or if investor confidence in the “existential narrative” wavers, the sudden withdrawal of capital could strand the Martian

settlement mid-development. Furthermore, the Michal thesis argues that this speculative drive may lead to a form of private governance where corporate entities prioritize the consumption and extraction of Martian resources over the rights and well-being of the colonists (Tepper, 2019). Without strong regulatory oversight, the anticipatory regime risks creating a planetary economy that serves the accumulation strategies of private capital rather than the socio-ecological needs of the community. The challenge for the Martian financing model is thus to harness the energy of astropreneurial speculation while embedding it within a transparent and equitable governance framework (Putro, 2020).

To diversify the funding base beyond the state and venture capital, the Martian economic model must integrate innovative financial technologies (FinTech) and decentralized funding mechanisms. Research suggests that crowdfunding, encompassing donation, reward, and equity-based models, can engage the global public as active stakeholders in the mission, providing a continuous flow of smaller-scale capital that is less sensitive to market volatility (Harris & Wonglimpiyarat, 2023a). Furthermore, the development of initial coin offerings (ICOs) and tokenized assets offers a path for mobilizing investment through blockchain technology, potentially creating a global “Martian investment pool” that bypasses the friction of terrestrial banking (NASA, 2025). These mechanisms allow for the democratization of space financing, ensuring that the mission is supported by a broad, international community of participants rather than just state agencies and ultra-wealthy individuals.

The application of FinTech on Mars also addresses the logistical challenges of interplanetary commerce, specifically the need for a medium of exchange that accounts for the communication latency between Earth and the Red Planet. Traditional credit-based systems that rely on instantaneous terrestrial verification are unsuitable for a settlement located light-minutes away. Cryptocurrency and smart contracts offer a solution by providing a decentralized and automated ledger that can function autonomously on the Martian surface (Harris & Wonglimpiyarat, 2023a). This financial architecture allows for the localized transfer of value, supporting an internal economy where settlers can trade resources and labour without the constant intervention of Earth-based financial institutions. By building these FinTech solutions into the foundational layer of the colony, planners can ensure that

the settlement possesses the tools for fiscal autonomy from the moment of arrival (Haqq-Misra, 2025).

However, the rise of decentralized finance in space also introduces significant risks regarding regulation, liability, and the potential for financial fraud. The absence of a clear international legal framework for extra-orbital FinTech means that initial Martian financial systems may operate in a “legal vacuum”, making them vulnerable to exploitation by corporate or state actors. To prevent this, the integration of these alternative models must be coupled with the development of new international space laws that define the rights and responsibilities of digital financial participants (Levchenko et al., 2019). Furthermore, the socio-economic critique of space commercialization warns that tokenizing Mars could accelerate the enclosure of the planetary commons, turning essential resources like water and air into speculative assets (Putro, 2020). Therefore, the use of FinTech must be carefully balanced with a commitment to preserving the “common heritage” of the planet, ensuring that financial innovation serves the survival and flourishing of all colonists (Sacchi, 2024).

The final stage of the financing evolution is the transition to a sovereign Martian economy, characterized by its own monetary system and localized capital ownership. A robust proposal for economic freedom on Mars suggests that the settlement can maintain long-term stability by adopting a full reserve banking system and a currency that is independent of terrestrial fractional reserve currencies. This sovereign approach is necessary to prevent the extraction of Martian wealth by Earth-based financial institutions, which would otherwise treat the colony as a permanent debt-dependent outpost (Haqq-Misra, 2025). By designating Mars as a “sovereign juridical peer”, the settlement can establish its own economic laws that reflect the unique physical realities of living in an extreme, resource-constrained environment. This localized control ensures that the “dividends” of Martian geography, such as the value of pressurized volume and energy production, are reinvested directly into the community (Michal, 2016).

The stability of this sovereign model depends on the settlement's ability to define its “carrying capacity”, which is the maximum population and industrial output that its geography and

technology can support. The Martian currency would effectively be anchored in this physical carrying capacity, turning essential assets like energy and oxygen into the “real wealth” that backs the monetary supply. This prevents the inflationary pressures typical of terrestrial economies, as the supply of money remains in balance with the settlement's actual ability to survive and expand. Diffusing the ownership of this capital among all citizens, rather than concentrating it in a few corporate hands, ensures a more resilient and equitable society where every individual has a stake in the mission's success. This approach transforms the colony from a “company town” into a vibrant, self-governing trust that prioritizes socio-ecological reproduction (Tepper, 2019).

However, achieving this financial sovereignty requires overcoming the initial logistics trap where the settlement remains reliant on Earth for high-tech assets and complex manufactured goods. During this transition period, the Martian economy must manage a complex “bi-planetary” financial relationship, maintaining exchange with Earth for vital imports while gradually building the industrial autonomy needed for decoupling. The challenge is to ensure that the initial debt incurred for colonization does not lead to a form of "neo-colonial" servitude, where the settlement's labour and resources are owned by terrestrial creditors. Sustaining a human presence beyond the exploration phase thus requires an economic model that balances high initial capital costs with a clear path toward localized sovereign wealth. Ultimately, the monetary and financial architecture of Mars will be the true test of the mission's sustainability, determining whether the settlement evolves into a free and flourishing civilization or remains a fragile extension of terrestrial capitalism (Putro, 2020).

4.3 The Influence of Martian Geography on Economic Models

The relationship between Martian geography and economic modelling is defined by a paradigm shift where the physical landscape moves from being a passive setting for human activity to an active economic agent that dictates the baseline of all capital expenditures. In traditional terrestrial economics, geography often provides a backdrop for trade, but on Mars, the exogeography is a lethal constraint that mandates a total integration of environmental

physics and financial planning.

The emergence of areopolitics as a distinct field of study highlights a fundamental shift in how Martian space is perceived, moving from a curiosity-driven scientific target to a territorialized economic frontier. Research published in 2024 and 2025 suggests that Martian territory and resources are increasingly being constructed through a resources-territory nexus, where the act of areometric mapping serves as a political technology of control (Tansel & Tilley, 2024). This nexus implies that territory on Mars is not simply discovered but is actively made through the commodification of environmental features, where the digital and robotic mediation of the landscape creates a new form of probe-power. By documenting and measuring the geological strata of the planet, actors do not merely collect data; they establish the informational foundation for property claims and jurisdictional boundaries (Knappenberger, n.d.). This process of territorialization is inseparable from the creation of resources, as the definition of a specific terrain as a commodity frontier essentially dictates the legal and economic framework that will govern its eventual extraction (Rapp & Inglezakis, 2024).

The interdependence of resources and territory within this nexus suggests that the exclusive robotic mediation of the Martian relationship has significant implications for future human governance. Because humans interact with the Martian landscape primarily through remote sensing and robotic rovers, the areometric data gathered becomes the primary tool for territorial strength. This strengthens the bond between the constitutive sub-elements of territory, terrain and land, and the resources embedded within them, making the questions of sovereignty and extraction effectively inseparable. As commodity frontiers widen, the spatial extension of nature appropriation via expanding territorial claims leads to a dynamic where the control of land is justified by the necessity of resource control (Young & Docherty, 2025). This relationship ensures that the first entities to map and measure high-value geographical sites like the Tharsis volcanic province or the northern basins are also the ones who define the initial rules of the planetary political economy (Tansel & Tilley, 2024).

The resources-territory nexus reveals that the framing of Martian landscapes is often used to

create an imaginary and material continuity between Earth and outer space, legitimizing settler futures. By rhetorically framing specific features of the Martian landscape as analogues to terrestrial frontiers, space-faring entities can normalize the expansion of capitalist structures and property rights into the cosmos. This areopolitically driven commodification risks the disenfranchisement of the global majority by prioritizing the interests of those who possess the technological means to measure and occupy these distant volumes. The influence of geography on economic models is expressed through this nexus, where the physical reality of the Martian terrain is used to anchor and justify the emergence of exclusionary governance regimes (Rapp & Inglezakis, 2024).

The financial viability of Martian colonization is inextricably linked to the concept of the gear ratio, which serves as a quantitative measure of the economic leverage provided by in-situ resource utilization. In the context of space logistics, the gear ratio represents the mass required in Low Earth Orbit (LEO) to deliver a single unit of mass to a specific destination. Recent analyses indicate that while the gear ratio for the lunar surface is approximately 2.5, the gear ratio for Mars is significantly higher, ranging between 8 and 10 (NASA, n.d.). This higher ratio implies that Martian geography offers a far more powerful natural subsidy than the lunar environment, as every kilogram of propellant or water produced on the Martian surface provides a 10-fold reduction in the mass that must be launched from Earth. However, unlike terrestrial economic models where resources are often fungible through global trade, this logistical leverage is non-transferable and strictly anchored to specific geographic coordinates (Levchenko et al., 2019). On Earth, a nation lacking oil can often purchase it through maritime trade routes, but on Mars, the absence of an established planetary transport infrastructure means that the 10x dividend is only available to those who physically occupy the high-value coordinates where water-ice and atmospheric feedstocks are most accessible (Knappenberger, n.d.).

This economic leverage is further enhanced by the comparative simplicity and reliability of Martian atmospheric processing compared to lunar regolith mining. The Martian atmosphere, composed primarily of carbon dioxide, can be harvested using Solid Oxide Electrolysis Cell (SOEC) technology, such as that demonstrated by the MOXIE project, which pull in the

atmosphere and pass it through electrolysis to produce oxygen. Unlike the Moon, which requires the complex and energy-intensive heating of tons of icy regolith or carbothermal processing of soil, Mars provides a ubiquitous and readily accessible feedstock in its air. When combining the higher gear ratio with the simpler processing requirements, the total mass savings in Earth LEO for a single Mars ascent are estimated at 240 to 300 tons, compared to only 10 to 14 tons for a lunar ascent. This staggering difference in return on investment highlights why the economic models for Mars are fundamentally driven by atmospheric and surface geography, as the planet's physical properties provide an inherent logistical advantage that lunar models cannot match (NASA, n.d.).

This spatial specificity creates a new form of areopolitical leverage that has no direct terrestrial analogue. While Earthly geopolitics often focuses on the control of chokepoints like the Strait of Hormuz or the Suez Canal to regulate the flow of existing goods, Martian leverage is constitutive; it is about the control of the sites that make the very existence of the colony possible. The entities that secure coordinates in the northern mid-latitudes, where the subsurface ice is both plentiful and accessible, effectively control the “printing press” of Martian mass.

The integration of this gear ratio into the cost-benefit analysis allows for a more aggressive expansion of infrastructure than would be possible under a traditional Earth-reliant model. By leveraging the 10x multiplier of the Martian gear ratio, mission architectures can redirect the saved launch mass toward delivering more sophisticated scientific instruments, habitat modules, and industrial equipment (Jones, 2016). This shift from propellant transport to infrastructure delivery accelerates the transition toward a self-sustaining settlement, as the colony can use its initial launches to establish the very tools needed to capture even more of the exogeographic dividend. The influence of the gear ratio on economic models proves that the sustainability of Martian colonization is not just a matter of technology but of geographical leverage (Levchenko et al., 2019). The strategic utilization of the Martian environment as a natural subsidy transforms the map of the planet from a scientific grid into a high-stakes arena of logistical real estate. The influence of the gear ratio on economic models proves that sustainability is not just a matter of technological progress but of

geographical positioning. This relationship ensures that the first entities to map and measure high-value geographical sites like the Tharsis volcanic province or the northern basins are also the ones who define the initial rules of the planetary political economy. This logistical leverage is the primary mechanism through which Martian exogeography dictates the feasibility of large-scale settlement, transforming the extraction of local resources into a direct financial dividend of immense magnitude that anchors the emergence of exclusionary governance regimes.

The economic layout of a Martian settlement is increasingly being modelled through sophisticated multicriteria decision-making processes, as exemplified by the Dvaraka Initiative. This initiative proposes a phased, three-decade plan to establish a self-sustaining settlement for 1,000 people, using four distinct degrees of criteria to identify the optimal geographic coordinates for habitation. The primary criteria include the potential for crop cultivation, the presence of a local magnetic field to reduce radiation exposure, and the scientific significance of the site for resource extraction. By applying these criteria to the Martian surface, the project identified the Jezero Crater as a prime candidate for settlement, due to its favourable watersheds and geological diversity. This approach treats site selection not merely as a technical challenge but as the determination of the settlement's carrying capacity, where the physical properties of the site directly dictate the social and economic complexity of the community that can be supported (Harris & Wonglimpiyarat, 2023b).

Differential rent, in the Martian context, refers to the varying economic potential of different landing sites based on their local exogeographic advantages. A site like Jezero Crater, with its western fan deposits and potential for subsurface water, provides a higher “rent” than a barren polar site by reducing the capital expenditure required for resource acquisition. The Dvaraka Initiative's methodology involves mapping global climate zones and ideal landing sites from a botanical perspective, ensuring that the chosen location can support the calorie requirements of a growing population through aeroponics and bioreactors. This site-specific economic model integrates technical specifications with architectural and social needs, suggesting that the “best way” to live on Mars is to align the settlement's layout with the environmental opportunities of the terrain. The geography of Mars influences the economic

model by forcing a transition from generic mission architectures to bespoke, site-driven settlements that are optimized for their local surroundings (Mukundan et al., 2023).

The use of multi-criteria decision-making (MCDM) and Geographic Information Systems (GIS) in site selection ensures that the settlement is built on a foundation of long-term self-sufficiency. By weighting criteria such as distance from fault zones, slope stability, and sunlight availability, researchers can rank alternative sites and minimize the risk of mission-ending environmental hazards. This rigorous geographic analysis is essential for justifying the acceptance of various locations for habitation, as it provides the data-driven certainty required to attract the massive private and public investment needed for colonization. The Dvaraka Initiative shows that the economic landscape of Mars is a product of these refined selection processes, where the physical geography of the planet is meticulously parsed to find the most efficient and sustainable path for human expansion. The resulting “economic layout” of the settlement is thus a direct reflection of the Martian terrain, showing that the influence of geography is embedded in every layer of the colony’s design and operation (Mukundan et al., 2023).

The use of natural lava tubes as primary habitats represents a transformative economic strategy that leverages pre-formed geological structures as a massive infrastructure subsidy. Recent comparative assessments highlight that subsurface sealing methodologies for lava tubes offer a superior cost-efficiency, with a lifetime cost estimate of 1.2 to 2.5 billion dollars compared to the potentially ten-fold higher costs of transporting and constructing lead-lined surface habitats. This “subsurface dividend” allows for a significant reduction in the mass and complexity of imported shielding materials, effectively using the Martian crust as the settlement's primary defensive layer (Harris & Wonglimpiyarat, 2023b). By transitioning from regolith-covered surface huts to subterranean cities, colonizing entities can achieve a level of scalability and safety that would be fiscally impossible through traditional engineering alone.

The economic value of lava tubes is further enhanced by their potential to house large-scale, pressurized environments with minimal mass penalties. However, the utilization of these

subsurface dividends requires a highly sophisticated exploration and surveying capability to identify intact and suitable tubes. The site selection process for lava tubes is an intricate geological endeavour, involving orbital imagery and robotic reconnaissance to ensure structural integrity and the absence of hazardous gas leakage. Once a suitable tube is found, the construction and sealing process presents significant engineering challenges that must be overcome through advanced ISRU techniques. Despite these hurdles, the long-term sustainability of a subsurface colony is seen as a more viable path than surface settlements, as it offers a level of permanence and protection that is essential for a mature society.

The concept of exogeographic sovereignty arises from the recognition that a Martian colony's carrying capacity is strictly defined by its local environmental and technological limits. In a model for economic freedom on Mars, the monetary stability of the settlement is predicated on its ability to maintain a localized currency system that is decoupled from Earth's fractional reserve banking (Haqq-Misra, 2025). This sovereignty is not merely a legal claim but a physical one, where the value of the Martian currency is anchored in the “real wealth” of the settlement, its pressurized volume, available energy, and calorie-producing potential. By restricting exchange with terrestrial currencies that are prone to inflationary pressures and wealth extraction, the Martian economy can ensure that the capital generated within the colony remains there to support its own growth. This model advocates for a full reserve banking system where the money supply is directly tied to the physical assets and carrying capacity of the habitat, ensuring that the economy remains in balance with its exogeographic reality (Michal, 2016).

The influence of geography on this sovereign model is expressed through the “carrying capacity” of the specific landing site, which dictates the upper bounds of the settlement's economic productivity. A settlement in a resource-poor region will naturally have a lower carrying capacity and thus a less stable or lower-valued economy compared to a settlement in a resource-rich heartland. This creates a powerful incentive for colonizing entities to secure the most productive geographic coordinates, as the strength of their sovereign economy depends on their command of the planet's physical dividends (Haqq-Misra, 2025). To prevent the rise of economically repressed or unfree societies, the principles of economic freedom,

such as property rights, regulatory efficiency, and open markets, must be integrated into the colonial governance structure. By diffusing capital ownership among all citizens, the colony can foster a resilient society where individuals are empowered to control their own labor and property, transforming the Martian settlement into a vibrant entrepreneurial frontier rather than a corporate dependency (Mukundan et al., 2023).

Exogeographic sovereignty is the final stage of the transition toward a mature and independent Martian society. The physical constraints of the Martian environment mandate a level of fiscal soundness and individual empowerment that is often lacking in terrestrial economies burdened by high debt and government overreach. By establishing a sovereign economic model that is worthy of a free people, Martian colonists can avoid the corruption and red tape of terrestrial systems, creating an efficient economy that conserves "the true, the good, and the beautiful" in their new home. This model of ordered liberty and free enterprise, as measured by indices of economic freedom, is the only way to ensure that the Martian civilization can thrive over the multi-century horizon required for true planetary autonomy. In this framework, the influence of geography is the catalyst for the creation of a new kind of human society, one that is defined by its stewardship of the planetary common heritage and its commitment to the prosperity of all its inhabitants.

4.4 Economic Lessons from Antarctica

The economic and structural maturation of a Martian colony finds its most significant terrestrial parallel in the historical and institutional evolution of Antarctica. As the human species enters the third great age of discovery, the transition from maritime circumnavigation to the exploration of abiotic, uninhabited regions has created a unique set of economic and legal problems that were first encountered on the seventh continent. Antarctica, like outer space, represents a spatiality that is qualitatively different from previous frontiers because it lacks indigenous human populations and self-sustaining biotas, forcing exploration to rely entirely on technologically mediated systems (Heinicke et al., 2021). This historical continuum suggests that the economic models applied to Mars are not emerging in a vacuum

but are instead the next iteration of a governance logic that seeks to interrogate and settle landscapes that are fundamentally hostile to biological life (Saint-Guillain et al., 2023). The lessons derived from the Antarctic experience, ranging from the management of the global commons to the economic cost of safety in extreme environments, provide a critical heuristic for predicting the fiscal and political trajectory of a Martian settlement (Haqq-Misra, 2025).

The classification of Antarctica as a global common serves as the foundational legal and economic baseline for this comparison. In the late 1950s, as the first satellites entered orbit, the international community drew directly from the Antarctic model to establish that outer space should remain outside of existing political borders and free from sovereign claims (Klicker et al., 2023). The 1959 Antarctic Treaty specifically established that the continent should be used exclusively for peaceful purposes and should not become the scene or object of international discord (THE ANTARCTIC TREATY, 1959). For Martian economic modelling, this implies that the initial capital of the planet is its status as a shared province of mankind, a designation that prohibits the traditional extractive models of colonial history (Karl E. Weick & Kathleen M. Sutcliffe, 2007). However, as witnessed in the Antarctic context, the legal ban on sovereignty does not necessarily prevent the emergence of power asymmetries, as those states with the technological capacity to maintain a presence in the region often exert a disproportionate influence over the rules of engagement (Pyne, 2016).

The Antarctic Treaty System (ATS) offers a robust example of a polycentric and stakeholder-driven governance model that has successfully maintained peace and facilitated scientific research for over six decades. This self-regulation by users ensures that the rules of the game are established by those who have a vested interest in the operational success and environmental stability of the frontier (Paul Arthur Berkman et al., 2011). The success of the ATS in providing a stable framework for international cooperation, even during periods of intense geopolitical tension on Earth, suggests that a Martian economic model grounded in stakeholder self-governance is more resilient than one imposed by distant central authorities (Saint-Guillain et al., 2023).

The history of resource management in the Southern Ocean provides a cautionary tale

regarding the “opportunity cost” of mineral extraction. The shift from the proposed extractive framework of CRAMRA to the preservationist Madrid Protocol was driven by the recognition that the environmental risks of mining outweighed the potential financial gains (Le Coze, 2024). The Martian minerals debate will likely face a similar CRAMRA moment, where the international community must decide if the exogeographic dividends of the planet are worth the risk of environmental ruin (Bushnell, 2021).

In the Antarctic model, scientific investigation functions as the primary currency for earning political standing and participating in decision-making processes. The Antarctic Treaty mandates that scientific observations and results shall be exchanged and made freely available, effectively turning knowledge production into a prerequisite for colonial legitimacy (THE ANTARCTIC TREATY, 1959). This science-driven economy creates a system where states invest in research stations and logistical networks not for direct fiscal profit, but for the “diplomatic ROI” (Return on Investment) gained through scientific excellence. Applying this to Mars, the early economic models will likely prioritize scientific output as a means of securing international recognition and ensuring that the settlement remains a peaceful realm of human activity rather than a site of territorial conflict (Klicker et al., 2023). This system will rely on a “subsidy-for-legitimacy” structure, where the cost of research and habitation is subsidized by the strategic value of the presence it maintains (Paul Arthur Berkman et al., 2011).

The role of science diplomacy in Antarctica has historically served as a stabilizing force, allowing for cooperation even between rival superpowers during the Cold War (Heinicke et al., 2021). For a Martian colony, the establishment of shared scientific standards and data-sharing protocols, as seen in the NASA Moon to Mars architecture updates, serves a similar dual purpose of technical efficiency and diplomatic stability (NASA, 2025). By anchoring the economic model in a shared commitment to scientific discovery, the colony can mitigate the risks of militarization and ensure that the infrastructure developed for research serves as a foundation for broader social and commercial expansion. This suggests that the first Martian entrepreneurs will need to operate within a hybrid economy where scientific contribution remains a key metric of their social and legal standing (Michal, 2016).

However, the dominance of science as the primary Antarctic activity is increasingly challenged by the rising pressures of commercialization and the dual-use nature of modern technology. As seen with the usage of commercial satellite services in recent terrestrial conflicts, research infrastructure possesses inherent military and commercial value (Sacchi, 2024). This implies that a Martian economy based purely on scientific research may be insufficient for long-term sustainability, as the logistical costs and the strategic value of the planet will eventually attract actors who seek to leverage these assets for broader geopolitical or commercial goals (Beery, 2016). The economic model must therefore be designed to handle the inevitable transition from a purely scientific outpost to a more complex and multi-functional planetary society (Young & Docherty, 2025).

The operational economics of life in an isolated, confined, and extreme (ICE) environment are clarified by the safety and risk management protocols utilized at Antarctic stations like Concordia. Because rescue in Antarctica is often impossible for months at a time due to environmental conditions, the cost of risk becomes a primary driver of the budget, necessitating a strategic sacrifice of certain safety margins to ensure mission fidelity (Tepper, 2019). This economic reality is directly applicable to Mars, where long transit times and communication delays make terrestrial-style emergency response a physical impossibility (Engler et al., 2019). The economic lesson from Antarctica is that the high fidelity of an analog mission, whether scientific or commercial, is intrinsically linked to the acceptance of high-consequence risks that would be considered unacceptable in a terrestrial industrial setting (Putro, 2020). Thus, the fiscal sustainability of a Martian base depends on its ability to internalize these risks, shifting investment from external rescue capabilities to internal redundancy and the psychological resilience of the crew (Roy, 2025).

Resilience in these environments is not just a psychological trait but a structural requirement that influences the design of every logistical system (Karl E. Weick & Kathleen M. Sutcliffe, 2007). The decentralized decision-making process of Antarctica contrasts with the highly bureaucratic and centralized management styles typical of large terrestrial organizations (Le Coze, 2024). For a Martian economy to remain stable, it must adopt a high-reliability organization (HRO) framework that prioritizes operational mindfulness and flexibility over

rigid strategic planning. The economic benefit of this approach is a reduction in the catastrophic failure rate, which is the single most important factor in protecting the massive capital investment required for colonization (Michal, 2016).

The cost of isolation is further manifested in the logistical complexity of maintaining a closed-loop environment where every resource must be accounted for and recycled. Antarctic stations serve as the primary terrestrial testbeds for these life-support technologies, demonstrating that the cost of stay is significantly higher than the cost of get (Bushnell, 2021). This necessitates an economic model that prioritizes resource circularity and the minimizing of waste, as the energy required to replace a lost resource is often higher than the energy required to recycle it. This economic logic leads to the development of a socio-ecological economy where the survival of the community is prioritized over the narrow accumulation strategies of private entities (Pyne, 2016). By learning from the operational difficulties of Antarctic resupply, Martian planners can build more robust and self-sufficient economic architectures that are less vulnerable to the logistical interruptions of interplanetary transit (Levchenko et al., 2019).

The role of private firms in this landscape adds a layer of complexity that was less prevalent during the early years of Antarctic exploration (Putro, 2020). This mirrors the early 20th-century whaling and sealing industries in Antarctica, which operated with minimal oversight before being brought under international regulation (Beery, 2016). The lesson here is that without proactive governance, the first commercial actors on Mars may establish a de facto property regime that is difficult to dismantle later (Tansel & Tilley, 2024). To avoid the pitfalls of unregulated extraction and markets, a Martian political economy must integrate these private actors into a polycentric framework that balances the drive for innovation with the ethical imperative to preserve the planetary commons (Sacchi, 2024).

Private space firms like SpaceX and Blue Origin are not merely service providers; they are becoming central to the strategic and economic architecture of the entire space sector (Radin et al., 2025). This complicates the Antarctic model of state-led science, as commercial entities may prioritize intellectual property and proprietary data over the freedom of scientific

investigation. For a Martian colony, the financing models must account for this tension by creating incentives for private firms to contribute to the common infrastructure and scientific baseline of the settlement (NASA, 2025). Failure to integrate these actors into a shared governance regime could lead to a fragmented economic landscape where competing corporate enclaves undermine the stability of the entire planet (Pyne, 2016).

The transition to commercialization also requires a re-evaluation of state responsibility as defined under Article VI of the Outer Space Treaty. In Antarctica, the activities of non-governmental entities are strictly regulated by their sponsoring states to ensure compliance with environmental and peaceful-use protocols (THE ANTARCTIC TREATY, 1959). On Mars, states will be held responsible for the national activities of their private firms, necessitating a robust regulatory framework that can withstand the unique pressures of deep-space commerce (Le Coze, 2024). This suggests that the economic models for Mars will be characterized by a high degree of state-private integration, where the legal stability provided by the state is as valuable to the commercial actor as the launch capability itself (Stover & Bukley, 2024). The resulting planetary political economy will likely be a hybrid system that utilizes the efficiency of the market while maintaining the strategic and ethical oversight of international law (Ferreira-Snyman et al., 2019).

The social reproduction of a Martian community requires the application of international human rights instruments in a setting where the environment itself is a constant threat to life. While technology is advancing to make these settlements possible, the legal rules related to the fundamental rights of individuals in such extreme conditions remain largely uncertain. The Antarctic experience shows that even in highly regulated scientific environments, issues of social order, labour rights, and individual liberty require clear jurisdictional frameworks (Saint-Guillain et al., 2023). For a Martian colony, the economic model must internalize the cost of providing and protecting these rights, as a society that fails to ensure the well-being of its members will quickly face the risk of internal collapse. This necessitates a transition toward a planetary political economy that prioritizes human security and social equity as much as it does technical survival (Beery, 2016).

The protection of human rights in space settlements is further complicated by the potential for private governance to prioritize corporate interests over civil liberties (Tansel & Tilley, 2024). To prevent the exploitation of the colonial workforce, the Martian economic framework must ensure that the ownership of capital and resources is diffused among the citizens, providing them with the economic freedom necessary to maintain their autonomy. By adopting a full reserve banking system and localized currency, the colony can protect itself from the extractive wealth dynamics that have characterized terrestrial colonial history (Haqq-Misra, 2025). This sovereign approach ensures that the dividends of the Martian environment serve the socio-ecological reproduction of the community rather than the accumulation strategies of distant shareholders (Ferreira-Snyman et al., 2019).

The economic lessons from Antarctica emphasize that the success of a Martian settlement will be determined by its ability to foster a cooperative society that preserves the common heritage of humanity. The transition to a sovereign Martian economy represents the final stage of this evolution, ensuring that the wealth generated on the planet remains there to support its own flourishing (Pyne, 2016). By applying the institutional, social, and risk-management lessons of the seventh continent, we can build a Martian civilization that is not only technically feasible but also economically sound and socially resilient (Heinicke et al., 2021). The resulting planetary trust model provides a new template for human flourishing beyond the limits of terrestrial constraints, turning the harsh reality of Martian geography into a source of enduring prosperity for all its inhabitants (Bushnell, 2021).

4.5 Risks of Economic Collapse

The economic maturation of a Martian settlement is perpetually haunted by the spectre of systemic collapse, a risk that transcends traditional terrestrial market recessions due to the absolute dependency of the population on technologically mediated life support. In a planetary context, economic collapse is not merely a period of negative growth but a potential extinction event where the failure of financial flows leads directly to the cessation of oxygen, water, and thermal regulation (Levchenko et al., 2019). By examining the structural parallels

between terrestrial critical infrastructure and the nascent Martian economy, we can identify escalation points where localized disruptions, such as a failure in in-situ resource utilization or a sudden withdrawal of Earth-based capital, can propagate through the entire socio-technical system (Marie, 2015). The resilience of the Martian economy depends on its ability to transition from a fragile, hub-and-spoke dependency on Earth toward a robust, decentralized sovereignty that can withstand the inevitable shocks of a multiplanetary existence (Haqq-Misra, 2025).

The pursuit of extreme efficiency in Martian architecture creates a paradox of systemic fragility, where the optimization of mass and cost results in a network architecture prone to self-organized criticality (SOC). In this regime, the settlement functions as a tightly coupled system where small perturbations can trigger avalanche-like cascading failures that propagate through interdependent critical infrastructures (Salvaña et al., 2025). This vulnerability is exemplified by the hub-and-spoke models utilized for early Martian logistics, where the failure of a single critical node, such as a primary water extraction facility or an orbital transshipment point, can disrupt the entire supply chain with devastating efficiency (Ferreira-Snyman et al., 2019). Recent theoretical modelling of extreme events suggests that catastrophic failures are often structural features of systems operating near critical thresholds, especially when those systems have been refined to minimize the margins of error for the sake of fiscal viability. Consequently, the economic stability of the colony is constantly at risk from the gradual accumulation of stress across its interconnected components, where a minor technical glitch can escalate into a full-scale planetary disaster (Engler et al., 2019).

This risk is compounded by the high degree of dependency on automated and nuclear-powered assets, which are increasingly central to the NASA 2025 architecture updates and the long-term habitation strategies. While the instantiation of nuclear fission power systems and autonomous mobility units enhances operational capacity, it also creates a single-source vulnerability where the failure of these high-value assets cannot be easily mitigated by manual workarounds (NASA, 2025). As communities become more reliant on these complex networks for their daily survival, the “black-sky thinking” required for resilience planning must account for prolonged power and telecommunications failures that could freeze the

entire internal economy. The remedy for such cascading disasters begins with recognizing that they are a permanent feature of isolated, high-risk environments, necessitating a shift from centralized efficiency toward decentralized redundancy. Failure to build these safeguards into the foundational economic architecture risks a scenario where the settlement reaches a point of collapse, leading to the total disintegration of the social and financial order (Salvaña et al., 2025).

The economic cost of maintaining this required redundancy is often at odds with the short-term profit motives of private providers who dominate the current space race. As the global space economy reaches record levels, exceeding six hundred billion dollars in 2024, the pressure to demonstrate immediate returns often leads to the erosion of safety margins and the prioritization of rapid deployment over structural resilience (Karl E. Weick & Kathleen M. Sutcliffe, 2007). This creates a tension between the state's role as a guarantor of safety and the commercial drive to lower launch barriers, where the “cost of risk” is frequently underestimated in speculative business cases (Marie, 2015). In an environment where rescue is impossible for months at a time, the internalization of these risks is not just a safety requirement but a core economic challenge (Heinicke et al., 2021). A resilient Martian economy must be designed to manage the dynamics of criticality itself, ensuring that the infrastructure remains flexible enough to absorb shocks without triggering the recursive toppling of the entire system.

The financing of Martian colonization relies heavily on speculative capital and a continuous influx of venture investment, creating a significant risk of an “astropreneurial bubble” that could burst before the colony achieves self-sufficiency. As of October 2025, the global space industry is characterized by a rapid surge in Series C funding deals and a high volume of startup activity in nascent sectors like orbital transfer vehicles and in-space manufacturing (ESA, 2025). However, market analyses indicate that revenue growth in these industries is lagging behind the optimistic expectations of investors, raising concerns about the long-term sustainability of the current investment trajectory. There is a growing consensus among financial analysts that the market is currently oversupplied with launch and satellite bus providers, leading to a consolidation phase where only a handful of large, consolidated

players are likely to survive. This oversaturation creates a fragile investment climate where a single high-profile failure or a terrestrial economic downturn could trigger a widespread withdrawal of capital, potentially stranding a Martian mission mid-development (Tansel & Tilley, 2024).

The concentration of eighty percent of venture capital into a limited number of dominant players, such as SpaceX, creates a systemic vulnerability for the entire sector. While these industry leaders have achieved remarkable technical milestones, such as the October 20, 2025, stacking of the Orion spacecraft for the Artemis II mission, their dominance creates a single-source dependency that complicates the economic landscape. If one of these central actors were to face financial distress or a loss of investor confidence, the entire logistical architecture of the Martian settlement would be placed at risk (Stover & Bukley, 2024). Furthermore, the transition toward national security customers as a primary source of funding in 2025 further politicizes the investment environment, making the Martian economy susceptible to shifts in terrestrial defence budgets and geopolitical priorities. This reliance on a narrow range of funding sources means that the Martian economy will not be at the beginning a truly independent entity but a precarious extension of Earth's military-industrial complex.

To mitigate these risks, the Martian financial model must diversify its mechanisms of capital acquisition beyond the current reliance on venture capital and state grants. Innovative models exploring the use of crowdfunding and specialized space-oriented bonds are beginning to emerge, but they remain in the early stages of maturity compared to traditional financing (Harris & Wonglimpiyarat, 2023a). The challenge for policymakers is to mind the gap between the current period of high speculative interest and the eventual maturation of a closed-loop Martian business case. Without a stable and diverse financial foundation, the risk of a sudden stop in investment remains a primary threat to the longevity of any planetary outpost. The stability of the Martian economy depends on the creation of robust financial architectures that can withstand the unique pressures of deep-space logistics and the inherent volatility of a nascent planetary market (Harris & Wonglimpiyarat, 2023b).

The most critical economic vulnerability of a Martian settlement is the “logistics trap”, where the high capital cost of resupply from Earth remains prohibitively expensive while local in-situ resource utilization (ISRU) fails to meet its self-sufficiency targets. According to the 2025 NASA architecture updates, the transport of thousands of kilograms of cargo to the surface is a primary driver of mission cost, with a focus on precision landing and autonomous offloading (NASA, 2025). This operational model is built on the assumption that the 10x gear ratio of Martian geography will eventually provide a natural subsidy that offsets these expenditures (Knappenberger, n.d.). However, if the development of nuclear power and mobility systems suffers from delays or performance gaps, the colony remains trapped in a state of Earth-dependency. This asymmetric relationship means that the settlement continues to function as a cost-centre for Earth, where any terrestrial economic instability can lead to a reduction in resupply cadence, potentially starving the colony of essential technical components or life-support reserves (Klicker et al., 2023).

The transition from an Earth-supplied model to an autonomous Martian economy is further complicated by the “hi-tech dependency” of the settlement. While basic consumables like oxygen and water can be produced locally through atmospheric processing, the colony will remain reliant on Earth for high-value assets such as medicines, microchips, and robotic specialized sensors for the foreseeable future (Levchenko et al., 2019). This creates a tiered vulnerability where the settlement might achieve biological survival but remains economically stunted due to its inability to produce the complex industrial tools required for expansion. If a terrestrial economic crisis leads to a disruption in these high-tech supply chains, the Martian settlement faces an “existential stagnation” where its growth is capped by the limits of its imported hardware (Haqq-Misra, 2025). This logistical tether ensures that the Martian economic model is perpetually subordinate to the fluctuations of the global space economy on Earth (ESA, 2025).

To avoid this trap, the Martian economy must prioritize a “rapid decoupling” strategy that focuses on the development of local additive manufacturing and metallurgical processing. By utilizing the confirmed mineral resources and metal ores on Mars, the colony can begin to produce its own structural components and basic electronics, reducing the mass penalty of

Earth-based resupply (Michal, 2016). This industrial autonomy is the only way to transform the settlement into a sovereign economic peer rather than a fragile dependency. However, the initial capital investment required to establish this industrial base is immense, leading back to the tension between state-led scientific missions and the need for private-sector industrialization (Harris & Wonglimpiyarat, 2023a). The risk of economic collapse on Mars is a battle between the “decay rate” of imported technology and the “growth rate” of local industrial capacity, a dynamic that will determine the fate of the first generation of Martian settlers (Levchenko et al., 2019).

The final vector of economic collapse is the human element, where the breakdown of social order and the erosion of individual liberty within a private governance regime can lead to the disintegration of the settlement's workforce. Critical ethical analyses of Martian settlements argue that they constitute a “moral hazard”, where the focus on planetary survival diverts resources and attention away from terrestrial solutions and risks the creation of unfree societies (Marie, 2015). Under a corporate-dominated model, the total dependency of the colonists on company-owned life support systems creates a power asymmetry that can lead to the exploitation of labour and the suppression of civil rights (Tansel & Tilley, 2024). If the economic structure is designed as a closed corporate ecosystem, reminiscent of company towns, the resulting social attrition and loss of morale can undermine the productivity and stability of the entire colony. Without a robust legal framework that protects human rights in extreme habitats, the risk of social collapse becomes as significant as any technical failure (Ferreira-Snyman et al., 2019).

This risk is amplified by the psychological pressures of life in isolated, confined, and extreme (ICE) environments, where the “cost of failure” includes the mental health and interpersonal stability of the crew (Le Coze, 2024). As missions increase in duration and distance, the need for operational autonomy and “self-scheduling” becomes an economic necessity to reduce the frustration associated with distant Earth-based management. However, in a profit-motivated private model, the pressure to maintain high productivity may conflict with the psychological needs of the inhabitants, leading to burnout, social friction, and a potential “brain drain” where the most skilled colonists seek to return to Earth (Karl E. Weick &

Kathleen M. Sutcliffe, 2007). The social capital of the settlement, its trust, cooperation, and shared identity, is therefore a vital economic asset that must be protected through inclusive governance models that prioritize socio-ecological reproduction over narrow extraction strategies.

The stability of the Martian economy depends on a transition toward a planetary trust model that ensures the equitable distribution of resources and the protection of individual freedom. By diffusing capital ownership and adopting a sovereign monetary system, the colony can foster a resilient society where every individual has a stake in the success of the mission (Haqq-Misra, 2025). This approach prevents the rise of exclusionary monopolies and ensures that the wealth generated from the Martian environment is used to benefit the entire community rather than distant shareholders. In this framework, the economic success of the mission is measured not just by its fiscal growth, but by its ability to maintain a free and flourishing society that preserves the common heritage of humanity in the face of planetary adversity (Levchenko et al., 2019).

Conclusions

The governance of Mars will not be defined by terrestrial borders, but by the rigid “hard constraints” of exogeography (Casagrande, 2021). Unlike the horizontal geopolitics of Earth, Martian power is vertical, dictated by the control of the “High Boundary” (Giordano, 2025b). The moon Phobos serves as the ultimate strategic fulcrum in this system; orbiting at a mere 6,000 kilometres, it functions as a planetary panopticon capable of near-continuous surveillance and real-time tele-operation of surface assets. Control over this orbital gateway grants a “sovereignty gradient”, effectively relegating Earth-based administration to a secondary role while the entity occupying the moon dictates the operational tempo of the planet below.

On the surface, political authority is fractured by a stark “hemispheric dichotomy” that splits the planet into two competing theatres of operation. The Northern Lowlands, specifically regions like Arcadia Planitia, constitute the “Resource Heartland”, offering the accessible water ice necessary for propellant production and economic autonomy. In contrast, the Southern Highlands and volcanic provinces provide “strategic depth” through massive lava tubes, which offer natural fortification against radiation and bombardment (Martin & Benaroya, 2023). This geographical divergence forces a trade-off between economic efficiency and physical security, suggesting that early Martian governance will not be a unified state but a bifurcated system struggling to balance the vulnerability of the industrial north with the security of the subterranean south.

This fragmented geography risks calcifying into a permanent social stratification. The use of lava tubes as the primary “High Keep” for command centres and high-value assets creates a physical architecture of inequality (Mazur et al., 2020). While the elite and critical infrastructure remain protected beneath the basaltic crust, the bulk of the workforce may be relegated to the cheaper, higher-risk surface domes necessary for resource extraction. This dynamic threatens to reproduce historical patterns of colonial exploitation, where the “geological profile” of the settlement maps directly onto its socioeconomic hierarchy, creating a society defined not by democratic consensus but by access to safe habitation

(Giordano, 2025a).

This exogeographic reality provides the necessary context to answer the central research question of this study: what are the primary obstacles to establishing a human settlement on Mars, and what strategies can mitigate them? The investigation reveals that the most formidable barrier is not the engineering challenge of spaceflight, but the widening disparity between the accelerating technological feasibility of colonization and the starkly underdeveloped political and economic frameworks available to support it. While private entities and state agencies are successfully conquering the physics of interplanetary travel, the lack of robust governance models creates a precarious “precipice of success”, where the physical ability to land on Mars outpaces the social maturity required to live there safely.

The immediate consequence of this disparity is the emergence of existential political risks, specifically the potential for a “Company Town” scenario. In the absence of a supranational legal container, the extreme dependence of settlers on proprietary life-support systems grants the infrastructure owner, likely a private corporation, unchecked power that functions as a form of “lethal tyranny”. The research indicates that without intervention, the “Terms of Service” of a private operator could effectively supersede human rights, reducing citizens to the status of assets within a corporate balance sheet and rendering the concept of consent meaningless in an environment where expulsion is a death sentence (Cockell, 2022).

To overcome these obstacles, the thesis proposes a dual strategy of legal suspension and economic localization. Legally, the implementation of an “Antarctic Exception” is identified as the critical mechanism to decouple operational control from territorial sovereignty, preventing the settlement from becoming a private fiefdom (Paul Arthur Berkman et al., 2011). Economically, the path to sustainability requires a transition toward “Exogeographic Sovereignty”, utilizing a full reserve banking system and localized currency to prevent the extraction of Martian wealth by terrestrial financial systems. Only by implementing these specific strategies can the settlement evolve from a fragile, dependent outpost into a resilient polity capable of safeguarding the long-term survival of the species.

The proposed governance solution for the early Martian settlement relies on the “Antarctic

Exception”, a legal framework derived from the 1959 Antarctic Treaty System. This model is identified as a viable blueprint to prevent the emergence of a “Company Town” scenario, where a private corporation could leverage its control over life-support infrastructure to bypass democratic oversight (Michal, 2016). Just as the Antarctic Treaty successfully “froze” the geopolitical competition of the Cold War by designating the continent as a reserve for peace and science, a similar intervention is required for Mars to forestall the “privatization of outer space” and the resulting fragmentation of the planet into unregulated corporate fiefdoms.

Central to this solution is the adaptation of Article IV, which functions as a “legal fiction” to suspend the question of sovereignty (THE ANTARCTIC TREATY, 1959). By establishing that no acts or activities taking place on the planet shall constitute a basis for asserting a claim to territorial sovereignty, this mechanism effectively decouples the right to occupy land from the right to own it. For a Martian context, this implies that while private entities like SpaceX may construct and operate habitats, their presence does not validate a claim to the surface itself, thereby neutralizing the link between occupation and ownership that has historically driven colonial conflict (Cheney, n.d.).

This suspension of sovereignty facilitates the creation of a Planetary Trust or “res communis” regime, where the settlement is legally categorized as a scientific preserve rather than a commercial colony. In this model, the extraction of local resources, such as water ice for oxygen and propellant is permitted solely for the operational survival of the community, strictly decoupling In-Situ Resource Utilization (ISRU) from the commercial logic of export and profit. This distinction ensures that the essential elements of life remain shared resources of the community rather than licensed products of a corporation, effectively protecting the fundamental human rights of the settlers from being superseded by the “Terms of Service” of a private provider.

The economic viability of a Martian settlement cannot rely on the short-term profit cycles of terrestrial markets; instead, it must be grounded in the specific exogeographic advantages of the planet itself. The analysis highlights that the sustainability of the mission depends on

capitalizing on the Martian “gear ratio”, a logistical leverage where the availability of atmospheric resources allows for a ten-fold reduction in the mass that must be launched from Earth, compared to only a 2.5-fold reduction for lunar operations. By prioritizing, as expressed earlier, ISRU, the settlement can effectively use the planetary environment as a massive natural subsidy, breaking the prohibitive “logistics trap” that would otherwise stifle growth through the immense costs of interplanetary resupply.

However, physical self-sufficiency must be matched by financial independence to avoid a scenario of “neo-colonial” servitude, where the colony remains perpetually indebted to terrestrial creditors. The thesis argues for a transition toward “Exogeographic Sovereignty”, characterized by the adoption of a full reserve banking system and a localized currency that is decoupled from Earth’s fractional reserve banking. This sovereign monetary framework would anchor the value of Martian currency to the settlement’s actual “carrying capacity”, its tangible reserves of energy, pressurized volume, and calorie production, thereby preventing the extraction of local wealth by distant financial institutions and ensuring that the economic dividends of the planet are reinvested into the community.

Furthermore, the fragility of the current “astropreneurial” investment landscape, heavily reliant on venture capital and susceptible to market bubbles, necessitates a diversification of funding mechanisms. To mitigate the risk of a sudden withdrawal of capital, the economic model must integrate decentralized financial technologies and global crowdfunding, fostering a broad base of stakeholders rather than a precarious dependence on a few dominant billionaires. Only by establishing this robust, autonomous economic architecture can the settlement withstand the inevitable shocks of isolation and ensure that the “profit” of the mission is measured in human flourishing rather than terrestrial ROI. The endeavour to colonize Mars transcends the technical objective of establishing a backup for humanity; it represents a fundamental ethical choice regarding the continuity of consciousness itself. While the survivalist argument posits that becoming multiplanetary is a moral imperative to prevent extinction, this thesis contends that mere biological survival is an insufficient metric for success. The true value of the mission lies not only in securing a safe harbour against existential threats but in the opportunity to preserve “moral agency” in the universe, ensuring

that the expansion of the species does not come at the cost of its universal values.

This expansion carries the profound risk of exporting terrestrial pathologies, specifically inequality, conflict, and exploitation, into the cosmos. By rejecting the logic of *terra nullius* and embracing the cooperative spirit of the Antarctic tradition, humanity has the capacity to decouple the settlement from the extractive dynamics of historical colonialism (Akbar et al., 2023). This shift allows for the creation of a socio-ecological economy where the dividends of the Martian geography, its water, energy, and shelter, are utilized strictly for the reproduction and flourishing of the community rather than the accumulation strategies of distant capital.

The future of the Red Planet will be determined by the wisdom of the institutional frameworks established before the first permanent boots hit the regolith. The responsibility of the current generation is to proactively design a civilization that is physically resilient yet socially just, ensuring that the “High Boundary” becomes a sanctuary for human flourishing rather than a new arena for geopolitical conflict. By harmonizing the “hard constraints” of exogeography with the highest ideals of liberty and cooperation, Mars can serve as a testament to humanity's ability to transcend its past limits and build a truly free and fair society among the stars. Realizing this high ideal requires conceding that the governance of extraterrestrial environments is a nascent field where theoretical maps must constantly adapt to emerging technological realities. Consequently, this thesis should be viewed not as a definitive conclusion, but as a foundational contribution to the rapidly evolving discourse on exogeography and space political economy. The limitations inherent in analysing a settlement that exists currently only in architectural plans invite further academic exploration to test and refine the strategies proposed herein. Future scholarship might fruitfully expand upon this research by subjecting the Antarctic Exception to rigorous legal stress-testing against specific corporate charters or by developing granular econometric models for the proposed sovereign currency systems. By providing a theoretical scaffold for these necessary debates, this work aims to ensure that the study of Martian governance keeps pace with the engineering feats that make it possible, offering the initial coordinates for a journey that is just beginning.

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