Life on Mars: Palimpsests of the Forthcoming Martian Res Publica

by

Nicholas Michael Puersten

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

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Abstract

Mars is set to be the new frontier of humanity, and as a result poses a unique set of architectural and engineering challenges to be overcome. Interest into both small and large-scale Martian settlements has greatly increased in the past several years, however many of these projects exist as sole entities within a foreign landscape, ignorant of site, culture, or temporal context. They cannot be considered towns and do not produce a valid form of public space as we know it.

This project aims to explore and suggest an alternative: a set of architectural frameworks based on vetted engineering solutions and urban design principles from which a uniquely Martian res publica could grow and thrive, all within the context of a long-term colonization and terraforming effort. Through diagrams, drawings, and written text, this thesis explores the growth of a settlement on Mars at three different stages of terraformation and attempts to understand the driving forces that shape how Martians might live.

Acknowledgements

I have to acknowledge Val, for consistently being excited about this project and having hour-long to sci-fi nerd out sessions, giving me a fresh desire to find new answers each time.

And Tracey, for always asking thought provoking questions and bringing a uniquely human aspect to this project.

Dedication

This project is dedicated to my family, and my partner, the ongoing support of whom compelled me to get it together and actually complete this project.

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LIFE ON MARS

PALIMPSESTS OF THE FORTHCOMING MARTIAN RES PUBLICA

NICHOLAS PUERSTEN

2022

Introduction 01

Preface

The concept of interplanetary architecture is far from novel. For millennia, philosophers, authors, artists, scientists, engineers, and architects have gazed out at some of Earth's closest heavenly bodies and pondered the possibility of planting one's own feet firmly on the surface. Some of the earliest known notions of extraterrestrial travel reach as far back as the oldest Vedic texts from the 19th century (Dimri 2021), while later cultures depicted tales of interplanetary battles, such as in Lucian of Samosota's *A True History* (Lucian 2014). Throughout human history, many of those depictions of interplanetary inhabitation have come from written science fiction or religious texts, the large majority imagining transhumanist worlds far from reality. Occasionally however, stories come along that begin to blur the lines between fact and fiction, merging fictitious elements with intricate knowledge of the operational nightmare that is keeping humans alive outside of Earth's atmosphere. In doing so, these stories reduce necessity for the suspension of disbelief, allowing us to glimpse into realistic potential futures.

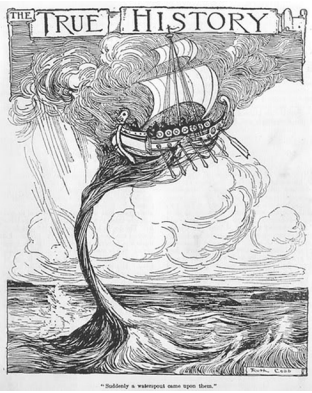
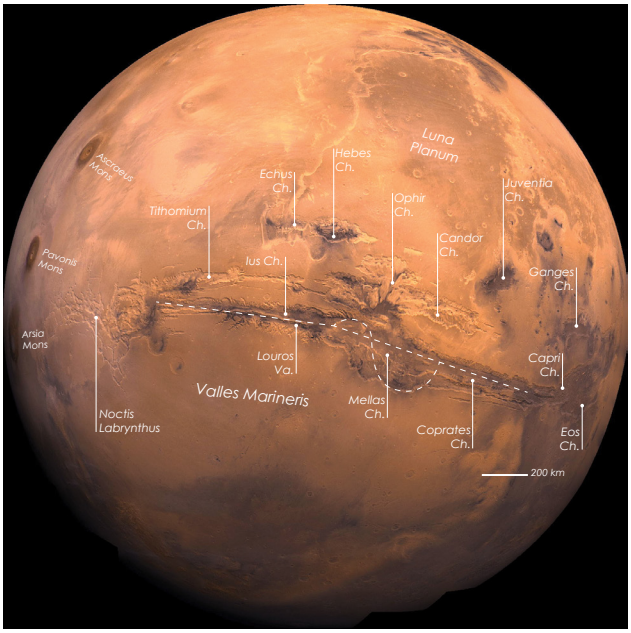


FIG 1_1 Cover of Lucian's A True History



DWG 1_1 Map of Mars' largest surface feature, Valles Marineris

In 1969, the bounds of human possibility were shattered when man took his first step on the lunar surface; the impossible had been achieved. Unfortunately, the intentions behind this dream were ill fated, short-lived, and it was not long before missions of such nature became unfeasible and were shut down – that is until recently. Continuous inhabitation of the International Space Station over the past 20 years has proven that humans can achieve some form of living beyond the boundaries of our home planet's atmosphere, but again, this is only the beginning of our extraterrestrial journey. With proposed lunar surface return missions slated for 2024 with the goal of establishing a permanent base, as well as the creation of functional space travel infrastructure to enable potential Martian colonization missions, the dream of transitioning science-fiction to science-reality is closer than ever before (Mars 2021). Achieving this millenniums-long dream has and will inevitably bring about fundamentally new questions on humanity's place within the universe – Are human beings alone in the milky way? Is complex life an Earth based phenomenon? How could life evolve on a non-Earth-like planet? I believe it is safe to say that questions of such a nature invariably have an influence on our design culture, and therefore the cities and architecture that will in due course be created.

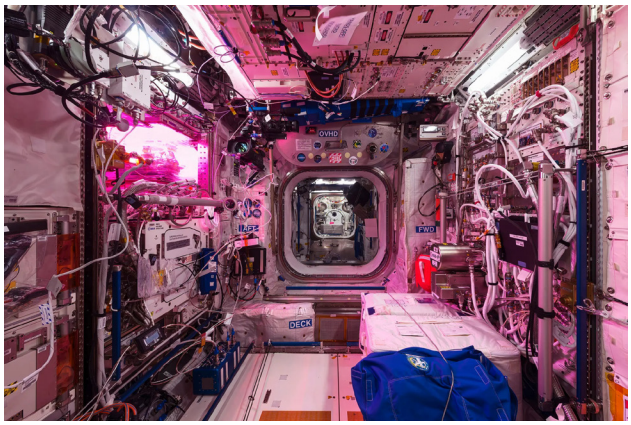


FIG 1_2 Interior Photograph of the International Space Station

Research Question

Currently, the aesthetic and functional state of extraterrestrial habitation can easily be likened to that of a submarine – all material choices, spatial restrictions, instruments, all intended for immense multi-functionality, much to the detriment of architectural expression. This can be seen throughout all additions to the ISS, in visualizations of NASA's Lunar Gateway, and in really any space-faring vehicle; they have been designed for the sole purpose of intensive research and are in no way 'new models for living'. This is all fine and well for the time being as the general cost for space travel is astronomical and the technologies required completely unmastered (relatively speaking). However, within the context of a long-term colonization and terraformation effort of the Martian surface, there will come a time when the concept of living on a surface beyond Earth's is no longer alien; when the technologies required to survive in outer space are far more easily attainable and well understood; when the purpose of interplanetary travel is no longer strictly research; when the prerogative is to truly live, rather than simply survive. At this point in humanity's timeline, the identity of extraterrestrial architecture and urban planning is up for grabs. Given the highly restrictive origins of interplanetary architecture and the predicted environmental changes that will occur as a result of terraformation, **how does the *res publica* begin and evolve from a space that Martian life can survive and live within, to a space where daily life can truly flourish and expand on the surface?** And what are the characteristics that become indicative of these Martian spaces as a result of all combined influences?

FIG 1_3 Proposed design of Lunar Gateway

Literature Review

A thesis project of this nature must be prefaced by the groundwork regarding the multi-phase, interdisciplinary mission that is transporting humans to the Martian surface, the leading theory regarding this venture being presented in Robert Zubrin's *The Case for Mars: The Plan to Settle the Red Planet and Why We Must* (Zubrin and Wagner 2021). He argued even back in its first edition (1996) that getting humans to Mars was a goal within humanity's reach, using solely current, existing technology. While most had argued that a mission of this scale was infeasible either due to unnecessarily large budget proposals or the requirement of faster propulsion technology, he quantifiably proved that these cost proposals were heavily inflated, and that the planetary alignment window for an Earth to Mars transfer negated the necessity for faster rockets. That is not to say that there are no skeptics to Martian colonization and terraformation, as some experts have stated that 'humans will never be able to make a significant impact on the atmosphere' (Dvorsky 2019). And while Dvorsky's comments have their own merit, the human spirit is strong and interest into not only getting human boots on Mars, but directly attempting colonization efforts has increased dramatically over the past few decades, and both public and private ventures have begun the lengthy process of generating the necessary infrastructure to achieve this lofty goal. Groups such as NASA, ESA, CSA, SpaceX (2002), and Blue Origin (2000) have spent years testing and perfecting propulsion technologies, preparing new space stations and deep space communications technologies, training multidisciplined researchers to perform complex situational tasks, funding research competitions for novel construction technologies and much more. Without the intense dedication of these people, the dream of expanding the human species beyond the bounds of Earth's gravity well would remain in the realm of science fiction.

FIG 1_4 SpaceX Starship Prototype

The pool of existing knowledge on general topics surrounding interplanetary inhabitation is considerably large and contains a wealth of in-depth research crossing many different disciplines. In no way could one project begin to cover the number of topics needed to fully flesh out a functioning design for a human civilization, therefore for the sake of brevity and the author's own sanity, the research covered will include, but not be limited to: construction methods and technologies, biological protection methods, and power and food production. On the other hand, the number of existing projects that directly seek to answer questions regarding extraterrestrial architecture are quite limited due to its highly speculative nature. The most relevant projects have been gathered below for study and comparison.

In 2015, NASA began funding the *3D-Printed Habitat Challenge* (ongoing) that required teams to design and fabricate prototypes for an autonomously printed Martian habitat, and to date the resulting proposals have been the most comprehensive approaches to interplanetary architecture to date, incorporating not only the immense operational requirements to keep humans alive on the Martian surface, but also the feasibility limitations ascribed by the nature of Earth-borne missions, and a sense of architectural value for the goal of mental wellbeing (NASA 2017). Some teams that have excelled greatly include SEArch+ (Space Exploration Architecture)/Apis Cor., Clouds AO, AI Space Factory, and Team Zopherus, each submitting multiple design strategies, prototypes, and research documents grounding their explorations in sound science aimed at autonomous construction and extensive in-situ resource utilization (ISRU) (Skelly and Rowe 2019). Some of the best projects coming from the SEArch+ team have proposed multiple construction methods for mitigating solar and cosmic radiation, easily one of the most harmful boundaries to overcome when designing Martian habitats (Yashar et al. 2019). Currently, the competition has been delayed throughout its final phases as the necessary infrastructure to begin the pioneering missions is put into place. One other design of relevance regarding construction technologies is that of the Liquifer Systems Group in association with the ESA, whose proposal for a Lunar research base was designed on the principles of the Additive Layer Manufacturing (ADM) of metals, polymers, and ceramics, and poses significant questions about recyclability (Liquifer Systems Group 2018).

FIG 1_5 HP Mars Home Planet Rendering Challenge - Winning Entry, by Max Rymsha

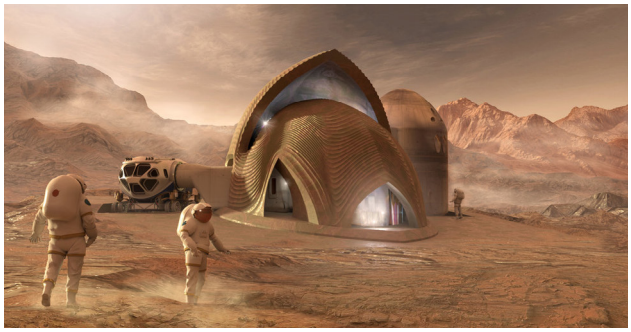


FIG 1_6 Mars X-House v1 by SEArch+, Regolith Radiation Shield

FIG 1_7 Mars X-House v2 by SEArch+, Reinforced Printed Regolith Pressure Vessel

All of these proposals have been aimed at perfecting the 'first habitat': an enclosure, the majority of which is to be autonomously constructed prior to human arrival containing all necessary life-support functions for a research team of four to eight people on a two-year mission. Of course, the possibilities for architectural expression then become highly limited due to the absence of human intervention and heavy restrictions, but beyond those first Earth-dependent habitats, explorations into large scale Martian habitats or cities become far and few in between and lean heavily into the realm of science fiction. One example of such explorations includes HP's *Mars Home Planet Rendering Challenge* (2017-2018), which simply asked competitors to render plausible images based on the prompt 'What does a city of one million people on Mars look like?' (Garage Staff

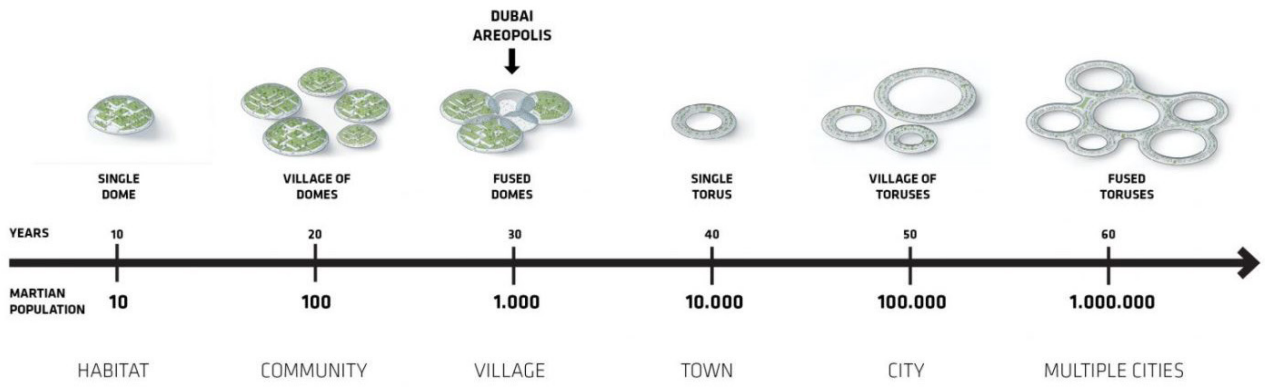


FIG 1_8 Stages of Tented Cities on Mars, BIG Architects

2018). This challenge was intended solely to be a visually creative endeavour; however, the requirements called for a general respect of the operational challenges of realistically harbouring humans in an alien environment. Around 1,000 submissions were submitted by over 90,000 individuals envisioning large scale settlements ranging from wildly creative and intangible to near believable. Alas, nothing more than some fantastical images came from this competition, with many of the winning projects envisioned large, enclosed cities – final products that echoed an inability for expansion outwards nor upwards. Another significant project that has sought to delve deeper into the meaning behind large-scale Martian design is BIG's *Mars Science City*, which envisioned both a set of design principles for evolving tented cities on Mars, as well as an Earth based simulant in Dubai (BIG Architects 2017). The proposed design principles reflect a strong parti of man-made environmental generation, a goal often associated with Martian inhabitation: terraformation. Their work on systems flow has been adapted for use throughout this project to aid in the plausibility of fabricating construction materials in early Martian missions. Further on systems flow, projects have been completed to attempt to emulate a functional closed loop system resource management as is required for

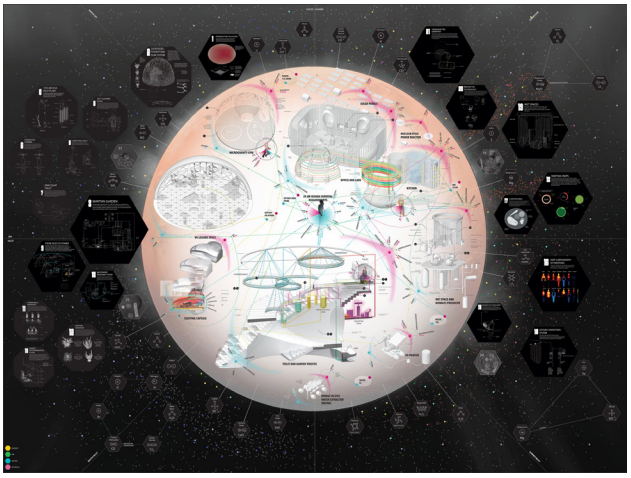


FIG 1_9 Moving to Mars: Closed-Loop Regeneration System, Lydia Kallipoliti

sustained life on Mars. For the London Design Museum's exhibition entitled *Moving to Mars* (Oct 2019 – Feb 2020), a team from the School of Architecture at the University of Technology, Sydney, led by Lydia Kallipoliti created a design project envisioning such a closed-loop system (Kallipoliti et al. 2020). Outlined in their design, water, power, air, food, and many other necessary life support systems were cycled through different forms of regeneration to avoid waste at all costs, a goal that could spell life or death for the first Martians.

Projects regarding the psychological impacts of humans on Mars have also been undertaken, such as in Dr. Joanna Kozicka's (Gdansk University of Technology) *Base on Mars (2006),* and *Martian Architectural Solutions* (2008) which outline physical aspects of the architecture seeking to aid in the mitigation of negative psychological effects that occur within 'isolated and confined environments' (Kozicka 2008). Similar research occurred in Space-craft's *Moon Village* (2018) that sought to understand the human dynamics of a confined community such as a research base (TU Vienna Design Studio 2018).

FIG 1_10 Perspective Renderings of Martian Architectural Solutions, Dr. Joanna Kozicka

Perhaps the most relatable expressions of human psychology in an extraterrestrial context however have been completed through works of science fiction, such as in Andy Weir's *The Martian* (Weir 2014). This story spectacularly outlines the incredibly tough operational requirements of simply staying alive in the early years of Martian colonization. However, even non-material aspects beyond human psychology have a significant impact on our design culture such as the socio-cultural, economic, and political aspects of dealing with larger group dynamics – even at a multiplanetary scale. James A. Corey's *The Expanse* Series (2011 – present) provides a narrative depicting Mars as a political force with rigorous intention to create a living ecosystem from the dry, barren surface. But perhaps there is no work of fiction best describing human dynamics in the context of interplanetary colonization and terraformation as Kim Stanley Robinson's *Mars Trilogy (Robinson 1992)*. The books explore a multitude of highly detailed character narratives describing believable human emotion over a complex, technically enriched timeline of Martian colonization, and has been recognize with multiple awards in turn. This trilogy is referenced heavily throughout this thesis project as much of the socio-cultural and political design by Robinson reflects desirable values of a possible Martian civilization.

Unfortunately, there exists a large disconnect between the heavily engineered architectural studies regarding small-scale, near future missions, and the fictional large-scale explorations completed generally through visual or written means. The natural progression of an urban fabric from single, localized habitats, to settlements, to large colonies will undoubtedly have an influence on the ways we design and construct on Mars. But this leaves some interesting questions as to the possible identity of a Martian res publica – what are the key influences of design as the public realm transitions from one of bunkered survival, to one of expanded surface living? And how is that public space intrinsically linked to its site as it undergoes centuries of terraformation?

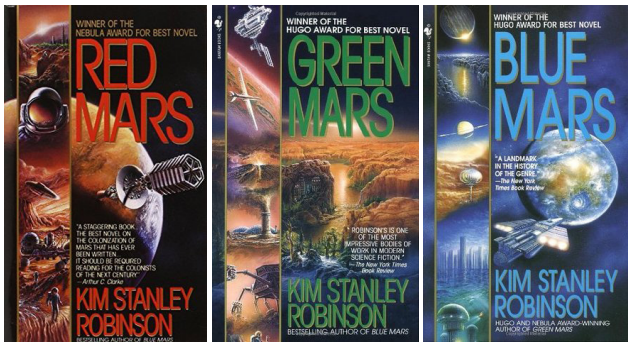


FIG 1_11 Mars Trilogy, fictional narrative surrounding terraformation of Mars by Kim Stanley Robinson

FIG 1_12 Kevin Lynch, Elements of a city

Hypotheses

As outlined above, many schools of thought currently exist on the topic of Martian inhabitation, and they typically lie within a spectrum ranging from science-fiction to science-fact. Given the current state of our extraterrestrial technology on one hand, and the wild imagination of many designers on the other, the alignment of many of those existing projects lies very close to either extreme end of that spectrum (ISS vs HP Mars Home Planet Competition), often ignorant to the merits and necessities of the other. As we move through the final era of humanity's restricted existence on Earth, the marriage of the two extremes is inevitable, as suggested throughout NASA's *3D Printed Habitat Challenge*. However, these specific examples exist within a very short timescale at the origin of the Martian timeline and are highly limited for space due to the restrictions of Earth dependency and research-based functionality. There will however come a point where this balance tips, and life on Mars will transition to self-sufficiency, proving an expert grasp on environmental manipulation within our habitats. This is the state of Martian inhabitation that I am most concerned with. Although incredibly fleshed out, each of these examples exists within a vacuum, unable to expand outwards and upwards. Based on my research into urban planning theory, I knew that cities are intrinsically tied to their landscapes, and often founded on some form of mythos that weaves its way into its architectural identity. So, at the point where Martian habitats transition to villages, and then to cities – what then is the architectural identity of the resultant res publica?

On top of all of this relevant information, the research question at hand requires the inclusion of both architectural and urban theory, the value of which cannot be understated. There are several other factors that I see becoming involved with this research when expanding these explorations to the scale of a functioning city, beginning with urban planning. Urbanism is a key factor in the creation and organization of any public space, whether intentional or not. Therefore, in order to provide a framework for the expansion of a city within a given site, an understanding of the principles of urbanist theories must be gained to enable reflection onto possible futures. This research began with an examination of Kevin Lynch's *A Theory of Good City Form,* and eventually moved to Joseph Rykwert's *Idea of a Town*, offering a backdrop of knowledge surrounding early elements of organized architecture and mythos (Lynch 1981; Rykwert 1976). Later on, elements of Aldo Rossi's *The Architecture of the City* and Leon Krier's *The Architecture of Community* slipped into the design process, informing the scale and layout of streets and urban blocks (Rossi 1982; Krier 2009). Each of these books offers a slightly differing perspective on the pieces of a city that come together to create the whole. By studying these different analysis methods, a series of targeted strategies that accommodate for the restrictions of extraterrestrial construction can then be applied to a specific site on Mars. Through this process, one can gain insight into a potential Martian *res publica*.

Principles of urban design however are intrinsically linked to human activity – whether it be social, cultural, political, ecological, agricultural, economical, etc. And with no real-life examples of extraterrestrial inhabitation beyond the brief period of moon landings, these values which are highly formative within a city's structure must be drawn from fictional stories and blended with the technological aspects required for such a mission. As identified in the literature review above, there is perhaps no better work of fiction envisioning those intricacies of human thought and engagement in a realistic Martian context than in Kim Stanley Robinson's *Mars Trilogy*, a series widely recognized for its strict scientific adherence, and its discussion on the inner machinations of humans as a response to the alien environment. Therefore, ideas relevant to the forming of towns and cities such as social laws and guidelines will be drawn from the trilogy in order to enable the application of urbanist principles.

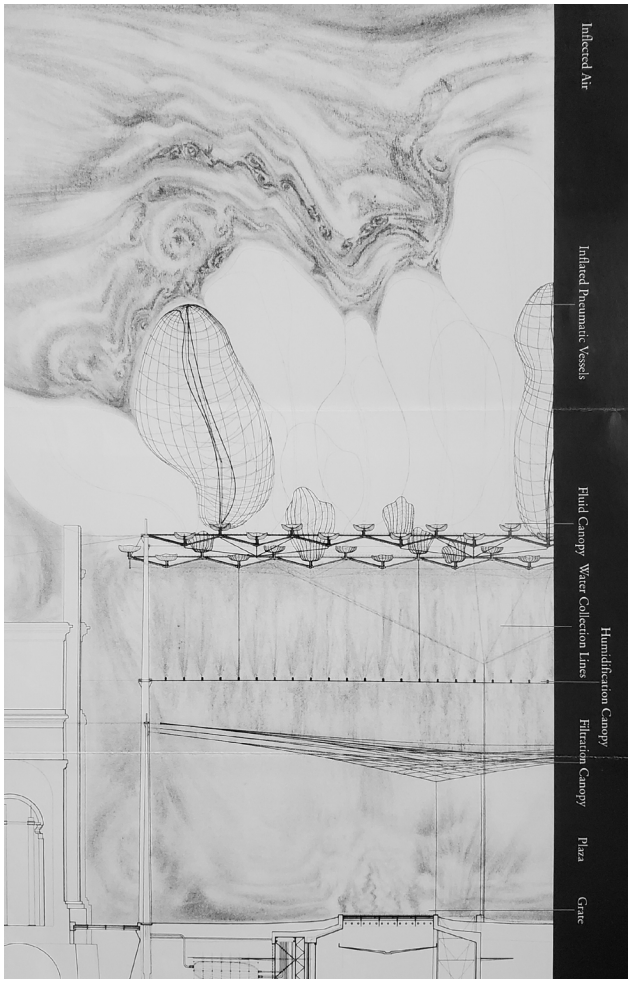


FIG 1_13 Building Section from Transubstantiating Cities, Danielle Wiley

FIG 1_14 Man and His World, Expo '67

Based on my current understanding of the unique aspects of Mars, its technological requirements and symbology in being the first human habitation outside of Earth, there are several architectural manifestos and projects whose function and parti greatly reflect those aspects and could be applied towards a resolution of the research question. One of such examples is Buckminster Fuller's geodesic dome, skillfully analyzed in Christine Macy and Sarah Bonnemaison's *Architecture and Nature: Creating the American Landscape* (Bonnemaison and Macy 2003). The project represents a turning point in architecture symbolizing the globalized nature of our modern world as a physical design element.

Other theoretical works that could aid in representing a potential Martian architectural identity includes research complete by Danielle Wiley in her 2002 thesis entitled *Transubstantiating Cities: Earthworks to Airworks* (Wiley 2002). Her thesis work revolved around designing mechanical interventions within an existing building that could visually represent all active fluid systems (groundwater, water supply, air currents etc.) in a physically discernable form. Representation of this kind applied to Martian inhabitation could aid in the tangibility of invisible and potentially deadly systems inherent with living on another planet, more specifically on Mars – the ever-present waves of solar and cosmic radiation, pressure differences and the intensely cold temperatures caused by a thin atmosphere, and perhaps most notably, the gravity differential that is so alien to the human condition. Perhaps architectural

representations of these systems could begin to reconcile human beings with their alien environment. Additionally, works such as Aldo van Eyck's *Twin Phenomena* and Kisho Kurokawa's *Symbiosis* might assist in reconciling the 'in-between space' – a way for Martians to experience both interiority and exteriority simultaneously, a relationship that is stretched to an extreme on Mars (Farhady and Nam 2009).

In using theoretical works such as these to inform the design of a settlement, a village, a city on the surface of Mars, a plausible path for development informed by both the strict technological requirements for settlements as well as the unique situation of extraterrestrial inhabitation can be formed. The goal of terraformation particularly opens an interesting trajectory, allowing a slow transition from focused survival to uninhibited surface life. This slow transition, when accounted for could allow for a layering of architectural typologies over centuries of ecological development, thus creating a palimpsest of the Martian res publica, each layer pointing to a specific era of colonization and the ideas prevalent at that time.

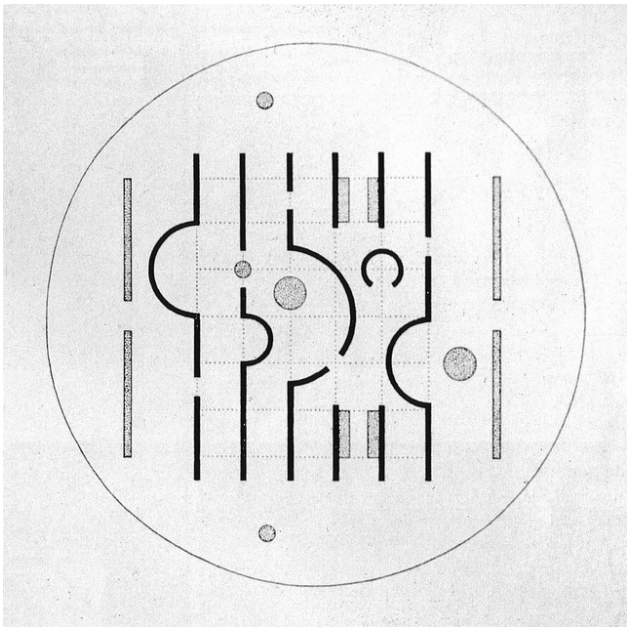


FIG 1_15 Plan of Sonsbeek Pavilion, Aldo van Eyck

Method

The first portion of this research will consist of examining the unique situation of Mars as a target for inhabitation. What conditions exist on Mars and what are the environmental barriers that need to be overcome in order to create viable living spaces? What is the process of terraformation and how will the planet change as this mission is undertaken? These questions begin to lay the foundation for Martian architecture and how it will develop over the years. Beyond questions about the planet itself, a better understanding of each of the previously discussed Martian engineering precedents must be formed, particularly those grounded in technological accuracy and architectural merit. As well, an understanding of technologies such as in-situ material utilization, autonomous 3D printing, and large-scale inflatable structures will provide a base set of plausible architectural typologies that might be combined and contrasted with one another. These typologies can then be built up as the atmosphere changes and technologies improve over the timespan of terraformation.

A site will then be chosen in order to begin the fabrication of a colony. This site will not be chosen solely for its scientific merit, nor for its geological magnificence (eg. Valles Marineris), but for its position within a projected terraformed Mars. Then in coordination with the aforementioned theories regarding urban development, features will be selected within the site to begin the lengthy process of development. As the context of Martian inhabitation is one of pioneering, resource utilization and transformation, there is potential that early generations of public living and community could reflect those primal values in contrast with newer, more global theories

While this process is all well and good for the building of an early, research-based settlement, given that the question at hand is that of Martian public space, there is a requirement for an added human element. This element must then be drawn from science fiction. Many talented authors have attempted a projection of what a Martian culture and social dynamic might look like such as in Ray Bradbury's *The Martian Chronicles,* James A. Corey's *The Expanse*, Andy Weir's *The Martian,* and Kim Stanley Robinson's *Mars Trilogy*. In analyzing stories such as these, it is not only possible to understand the many possible mindsets of humans in a Martian context, but also the political, economic, social, cultural, and divine potentials that could arise as a result of interplanetary inhabitation. In this author's opinion, the story formed within Robinson's *Mars Trilogy* poses the most interesting political and cultural milieu, and thus will be referenced heavily throughout this thesis, providing the majority of the human perspective. These positions can then be reflected onto the studies of engineering technology and urbanization policy to begin to construct livable public spaces that reflect the many values that Martian humans could exhibit.

By combining these three coinciding strings of research: Martian planetary science, construction technologies, and anthropocentric science-fiction, the previously selected site features will then be developed and shown at key points throughout the centuries-long process of terraformation. Through diagrammatic sections, the relational aspects of public space will be examined in each of the site elements. Following this examination, specific details will be extracted for further development to show the layering of infrastructure and architectural design as the transition from survival to flourishing occurs. Finally, a set of perspectives will be created in order to show how public life might be materialized in this palimpsest of Martian architectures.

Impact

Humanity is on the verge of a technological breakthrough in space travel, and as a result: interplanetary inhabitation. This new phase of human existence raises some fundamentally altering questions about humanity and its relationship with the cosmos, as well as our relationships with other humans, the answers of which have significant reflection within the spaces we design and inhabit. I hope to explore these questions of daily Martian lifestyle in context with vastly expanded applications of the recently explored engineering technologies. In doing so, these explorations will shed light on existing Terran models of complex urban development, reflect uniquely architectural questions about the ethics of colonization, and explore new models of material and land ownership; a reflection of issues that we continue to seek solutions for here on Earth.

Given that Earth is on the verge of vast global climate changes, Mars also poses a unique opportunity to show how civilizations can be constructed to coincide with radical climate changes, as opposed to resisting them. What happens when buildings and cities are constructed under the implication of centuries long use and reuse as opposed to short term profit?

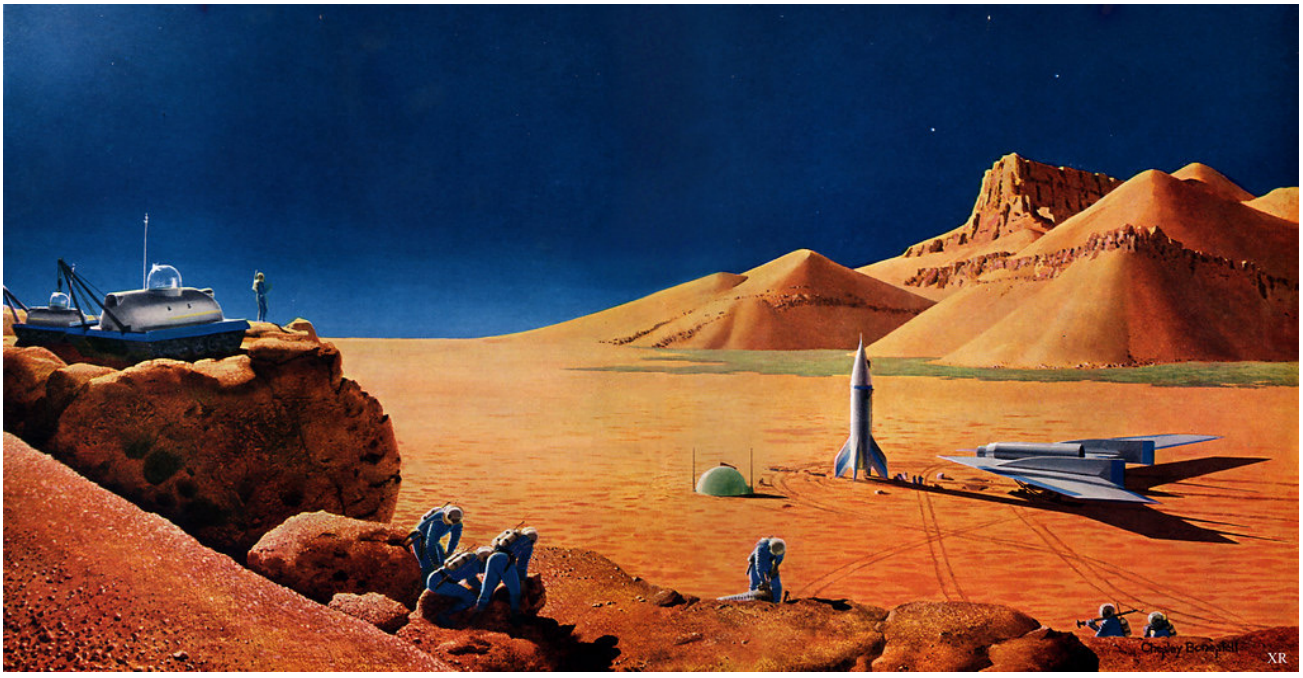


FIG 1_16 'The Exploration of Mars', Chesley Bonestell, 1956

Human's incessant desire to push the boundaries of space exploration have contributed greatly to our modern every day lives and in the eyes of this author, architecture is no exception to this improvement. Therefore, exploring new models of life and public space on another planet will undoubtedly lead to drastic improvements back here on Earth.

"Look at the pattern this seashell makes. The dappled whorl, curving inward to infinity. That's the shape of the universe itself. There's a constant pressure, pushing toward pattern. A tendency in matter to evolve into ever more complex forms. It's a kind of pattern gravity, a holy greening power we call ***viriditas****, and it is the driving force in the cosmos. Life, you see. [...] It's a holy feeling, and our task in this world is to do everything we can to foster it. And one way to do that is to spread life everywhere.* ***To aid it into existence where it was not before, as here on Mars."***

Green Mars, pg. 9
Kim Stanley Robinson

Designing for Mars 02

Why Mars?

Many have criticized the lofty grail of Martian colonization, and for good reason. Realistically, Mars is a deadly, unforgiving wasteland by any human standard, and will require great sacrifice from the pioneers who undertake such a mission. There are, however, many compelling arguments as to why humans should not only visit but attempt to colonize and terraform Mars.

Perhaps the most obvious advantages are the technological advances to everyday life that could result from a long-term mission to Mars. Many everyday technologies such as phone cameras, laptop computers, and air purifiers, to name just a few, have been created or rapidly advanced as a result of space ventures (Green 2019). The need for ingenuity and invention on a mission as complex as planetary colonization will undoubtedly return significant advancements in new and existing technologies, with potentially advantageous developments in the realm of nuclear power (Picot 2022).

Beyond technology, there are perhaps more compelling reasons to attempt colonization and terraformation of Mars. In his book *The Case for Mars: The Plan to Settle the Red Planet and Why We Must* (2021), Robert Zubrin discusses the cultural benefits of undertaking such a venture. He argues that humanity requires a 'new frontier'; a life away from existing rules and bureaucracy in which a new status quo can be sprouted and evolve. The colonization of North America offered a world in which aristocracy no longer mattered, and democracy could take a foothold (Zubrin and Wagner 2021). Others theorize that within the current late stages of capitalism, globalization has allowed the recreation of oligarchy in which a few very wealthy groups and individuals control the vast majority of the economy (Russo 2021, 584-596). Russo goes on to suggest that this has directly led to vast societal inequalities, and thus poorer social cohesion and effectiveness of democracy. Regarding Mars, Zubrin holds firm that such a destination is far enough away from the domination of the globalized world to become the 'new frontier'; to be the spark that advances humanity beyond our current cultural homogenization and technological stagnation (Zubrin and Wagner 2021).

FIG 2_1 *Pascal Lee's* "Mars Crater Drive-By", *Oil on Board, 2020*

Interestingly enough, similar theories are suggested within the world of science-fiction. In *Blue Mars*, Kim Stanley Robinsons discusses a theory of 'Harmony' as a final evolution of economy. He alludes to the idea that all human economies are not standalone entities, but constant recombinations of both the preceding and future states of the society and economy (Robinson 1996). For example, he theorizes through narrative that Feudalism formed from the contrasts of its predecessor religious monarchy and the emerging system of capitalism. Capitalism itself then formed from the residual feudalism and the emergent 'democracy' (which somewhat reflects the ideas of Marx's Socialism). *Blue Mars* theorizes that the act of colonization itself sparked a new renaissance and the transition to true democracy, formed from residual capitalism and an unknown future state entitled 'Harmony'. Although this debate is contained within a fictional narrative, it offers plausible insight into the ways that interplanetary colonization could affect cultural and economic systems.

In my own perspective, Mars offers an incredibly unique frontier combining the circumstances of extreme survival mirroring early human settlements, an intelligent population knowledgeable of the history of human culture and economy, and a strong common goal: bring life to the planet through terraformation. This set of factors will have significant implications for the formation of a culture, mainly through a deep respect for the rarity of life in the universe, and as a result, rooting said culture in empathy and equality for both the individual and the entire biosphere. These fundamental shifts would affect not only the citizens of Mars, but also the creation and usage of the public spaces within villages, towns, and cities.

Environmental Constraints

While its optimistic to consider the benefits that could arise as a result of successful colonization and terraformation, its important to keep in mind the limitations and ramifications of leaving our home planet. Simply put, humans do not fare well for very long in outer space (that is without extreme countermeasures). As biological beings, we are the product of billions of years of evolutionary success. This unfortunately comes with a significant drawback – our bodies are designed specifically to succeed in their natural environment: Earth's temperate surface (more specifically, its atmospheric composition and pressure, its specific gravity, and its immense magnetic field). This is one of the logistics that makes interplanetary travel for humans incredibly difficult.

Mars' planetary makeup differs greatly from Earth. Roughly speaking, it is a cold, dry, inhospitable wasteland, and cannot sustain human life in its current state – that is, not without either intense mitigation or modification. To properly mitigate these forces however, it must be understood how exactly the two planets are different.

To begin, Mars has little atmosphere compared to Earth. Based off of collected evidence, it is presumed that Mars did once have an atmosphere as thick as Earths, however much of it was swept into space (Wilson, Steigerwald, and Jones 2017). At sea level Earth's average pressure sits at 101,325 Pa, and only differs to inhospitable levels at extreme ocean depths or mountainous heights. Mars on the other hand has an average surface pressure of around 600 Pa, only 0.6% that of Earth's. And while Earth's atmosphere is composed mostly of Nitrogen (78%) and Oxygen (21%) the latter of which humans rely

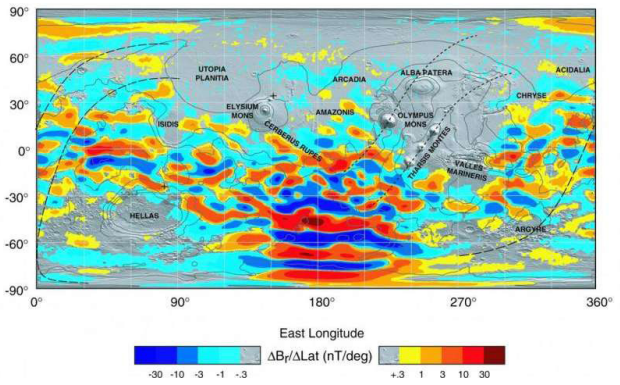
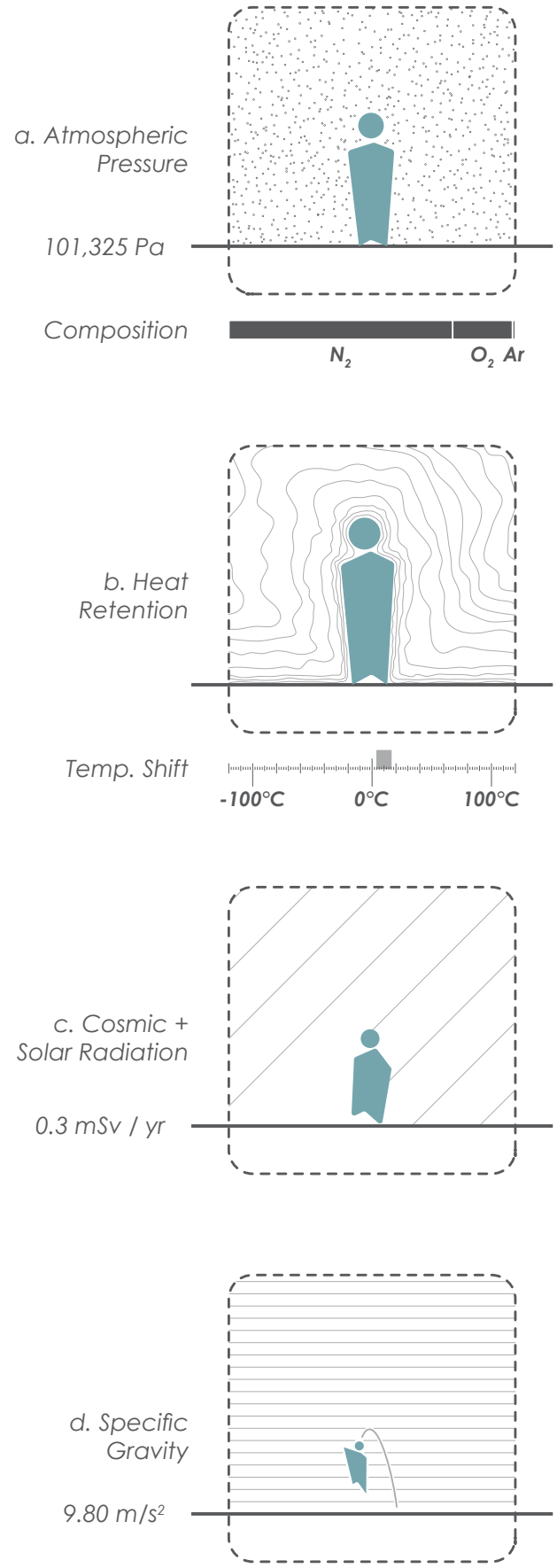


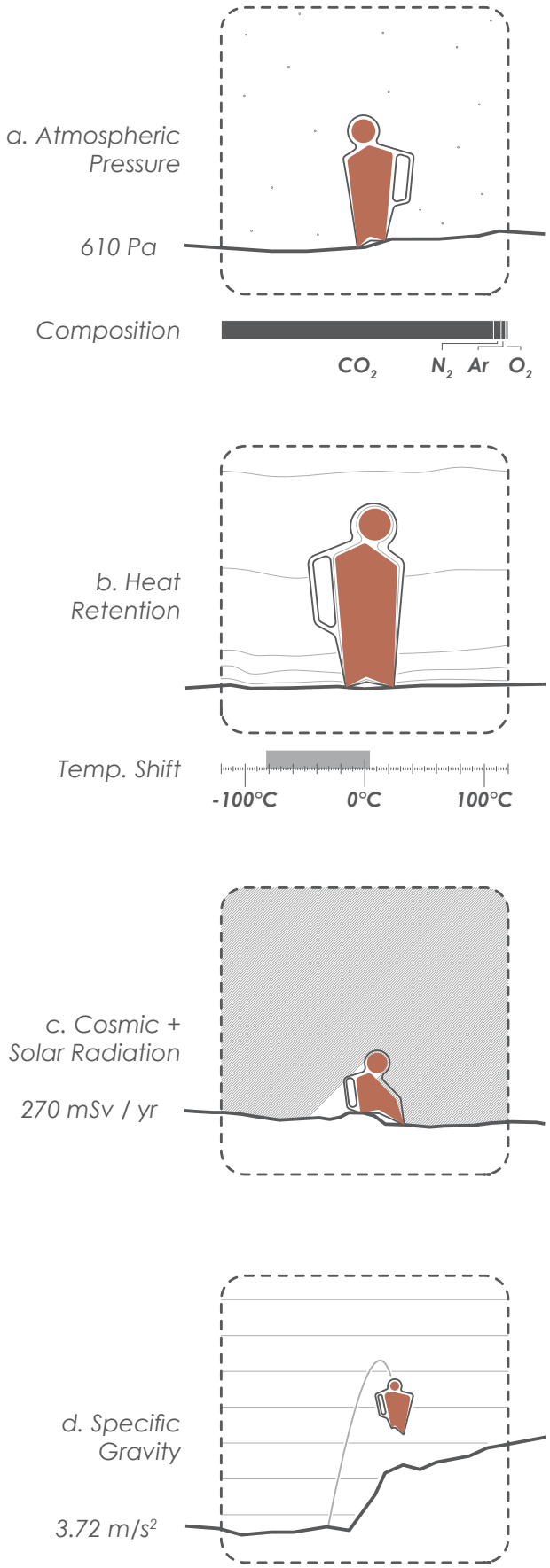
FIG 2_2 Map of Mars' Magnetic Crust

on for survival, Mars' atmosphere is composed of 96% carbon dioxide, and only contains trace amounts of Nitrogen and Oxygen (Dwg 2_1a/Dwg 2_2a). Its low atmospheric pressure also creates little greenhouse effect; Mars cannot retain a significant amount of thermal energy to stay warm. So while the temperature in a typical day-night cycle on Earth might fluctuate 5-30 degrees Celsius, Mars' surface temperature can fall as much as 100 degrees Celsius during a single night, with minimal heat coming from the regolith itself due to poor heat retention (Martinez et al. 2017, 295-338) (Dwg 2_1b/Dwg 2_2b). Therefore, Mars' atmosphere is thin, dry, toxic, and extremely cold, and unmitigated exposure on its surface would equate to relatively quick, but painful death. Already adding up to a seemingly unlivable environment based on atmosphere alone, there are other significant factors to consider when planning human habitation on Mars.

Radiation is easily the most insidious challenge we face upon leaving our home planet. Earth is surrounded by an immense magnetic field that is generated by the movement of its molten core and the geodynamo effect created as a result (Demorest 2001, 1-2). This magnetosphere acts as a barrier between life on Earth and both the intense radiative energy of solar winds and the never-ending barrage of cosmic rays from the interstellar medium (creating both the Aurora Borealis and Australis as a result). Upon leaving this magnetosphere however, humans (and most life as we know it) begin to have an exceedingly difficult time protecting ourselves. Radiation can cause significant defects in both the short and long term. If acute radiation sickness does not occur due to high dosage, prolonged exposure can lead to long term ailments including but not limited to damage to the nervous system, chronic degenerative tissue diseases, and cancer (Onorato, Di Schiavi, and Di Cunto 2020). The unfortunate reality of Mars however is that its core does not generate a geodynamo as Earth does and therefore cannot protect the surface from most of the cosmic and solar radiation (Stevenson 2001, 214-219). Mars does have magnetic fields generated by features in the lithosphere, but they are significantly smaller and weaker compared to Earths relatively uniform magnetosphere (Langlais and Quesnel 2008, 791-800) (Fig. 2_2). Unfortunately, they are not understood well enough at the current time to be a



DWG 2_1 *Visual Respresentation of environmental survival factors on Earth*



DWG 2_2 Visual Respresentation of environmental survival factors on Mars

source of significant protection from cosmic radiation. All this means that during one Earth year of time spent exposed on the Martian surface, an astronaut would receive 240-300 millisieverts of cosmic and solar radiation (Hassler et al. 2014, 389), a dose significantly higher than Earth's typical yearly exposure of 0.3 millisieverts from cosmic sources (increasing with altitude) (UNSCEAR 2010, 4) (Dwg 2_1c/ Dwg 2_2c). Without significant intervention, extended life on the surface would be wholly impossible for humans.

One key factor of interplanetary travel is the gravitational constant. As most human beings will likely never experience any significant form of microgravity, it's difficult to truly understand what standing on another planet would truly feel like. Given that Mars is only 15% the mass of Earth, its specific gravity sits at 3.71 m/s^2, ~38% of Earth's (Williams 2021) (Dwg 2_1d/ Dwg 2_2d). While this lower gravity environment could be interesting for short periods, the effects of microgravity on the human body are significant and require years of therapy to restore bone loss for even short missions (Wolfe and Rummel 1992, 281). The first colonization missions will be the longest ever performed to date, and it is likely that the first people to visit Mars will have irrecoverable bone loss, and without strict diet and aerobic exercise, will lose muscle as well (Abadie et al. 2021). On the other hand, some believe there is potential that humans might adapt to the gravity of Mars over multiple generations to have thicker bones and taller skeletons among a myriad of other environmentally responsive changes (Starr 2020). As a result, the architecture created for Martians must adapt as well, responding to physiological changes in future generations.

If all of that was not enough, Mars has one other defining feature that poses great difficulty for potential inhabitation: dust. Over billions of years, Martian wind has ground the dry regolith of the Medusae Fossae into a dust finer than any found on Earth (Ojha et al. 2018, 2867-7). While these Martian winds often blow at about 4-15 km/h, speeds on rare occasions can reach over 100km/h that can quickly bury the planet in global dust storms that can linger for months (Rover Environmental Monitoring Station 2022). These storms, while seemingly dangerous, do not pack a very serious punch as Mars' atmosphere does not have significant enough density to provide any pushing power, and the amount of dust carried by these storms only enough to deposit thin films (Mersmann 2017). What makes this dust difficult to deal with its both its size and composition. Martian regolith has been found to contain a significant percentage of Calcium Perchlorate (Kounaves et al. 2014, 226-231), a substance that once ingested by humans, can cause significant health defects and even death by limiting iodide uptake into the thyroid gland (Davila et al. 2013, 321-325; Steinmaus 2016, 136-143). Keeping this toxic dust out of habitats and away from humans then becomes a challenge that both architectural sequencing and programming can aid in.

Each of these differences on their own are a significant challenge to be overcome, together however they become a monumental barrier to achieving continued life on the Martian surface. Intense preparations must be made to counteract these factors and give the pioneers a fighting chance. On the upside, research is continuously being done and technologies invented and refined for the specific task of combating these elements.

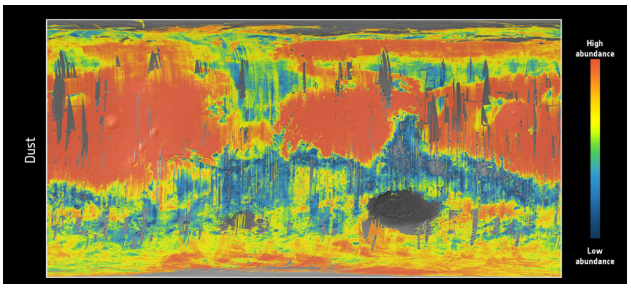


FIG 2_3 Ferric Oxide Dust Abundancy Map, ESA

Surface Conditions

The surface of Mars is an incredible palimpsest of geological history, covered in diverse surface features dating back to the Noachian Era. Some features of the landscape stand resolute, only worn down lightly over eons of abrasion, while dunes and other soft formations shift in an endless dance of the Martian winds. This leaves a variety of surface conditions that explorers could encounter when first visiting the planet, each with their own impact on resource availability and overall survivability. Its important to note that these conditions are grounded in the current state of the Martian ecosphere, and that attempts at terraformation would in all likelihood distort or even bury significant portions of the landscape. In that case, the illustrated conditions are important factors for early explorers' survival and will hopefully be better understood through years of inhabitation.

Dwg 2_3a.

As mentioned earlier, Mars is plagued by a substantial amount of surface dust that is often redistributed by regional or global dust storms. One result of these storms is significant depositions of dust on the surface that build up to impassable depths, with some areas reaching depths greater than 20 metres (Mangold et al. 2009, 23-32). Areas like this would be incredibly difficult for visitors to navigate as heavy machinery such as landers or rovers would likely sink beneath the thick dust. The European Space Agency has created a map of ferric oxide dust abundancy through the use of the OMEGA instrument aboard Mars Express that gives some idea of where these deep deposits could exist (Fig. 2_3).

Dwg 2_3b.

There are other areas of Mars away from the never-ending streams of deep surface dust where a mixture of soft and hard regolith has been exposed for eons, such as in Noachis Terra. Here, the surface rock is hard and unforgiving, offering poor access to minerals or water. This terrain is extremely difficult to navigate as the built-up ejecta of billons of years of meteorite impacts creates a very uneven surface pock with deep craters and hills.

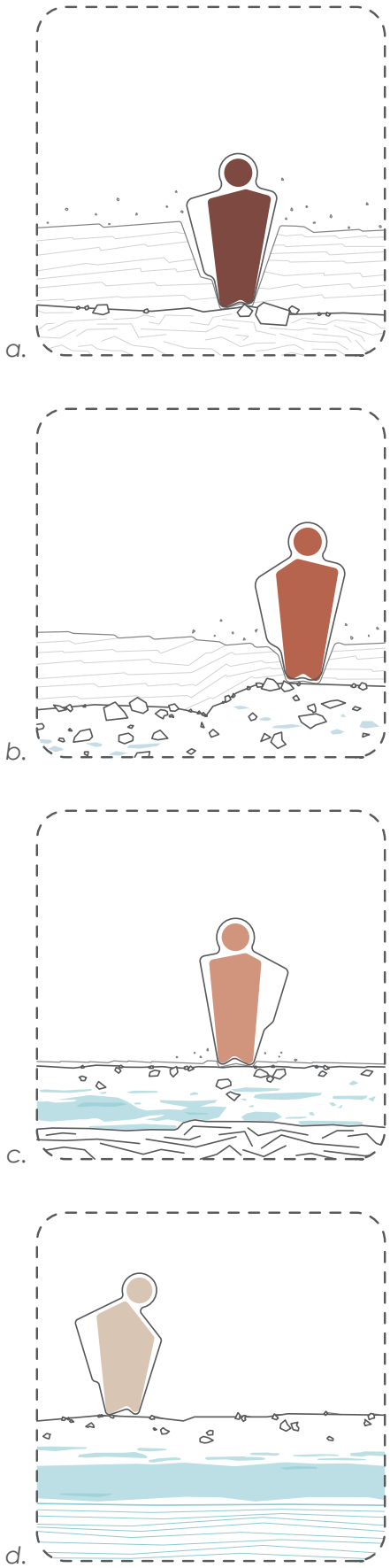
Dwg 2_3c.

Other more favourable conditions include areas where surface regolith is broken up and basalt stones are sparse, but where water ice begins to form into a sort of permafrost within the loose rubble. NASA estimates that there is a significant amount of water ice within 30 centimetres of the surface, as shown in their map created through data found by MRO's Mars Climate Sounder and the Thermal Emission Imaging System (THEMIS) aboard on Mars Odyssey (Fig. 2_4) (Greicius 2019). These areas are likely to be a significant source of liquid water for explorers as the regolith can be separated and used for construction purposes. The presence of bedrock below could also be an optimal surface for habitat foundations.

Dwg 2_3d.

Only existing within hypothesis at this point, some researchers provide convincing evidence towards a groundwater system on Mars (Salese et al. 2019, 374). Ice shelves could potentially protect liquid water below the surface, and if true would be the most significant source of water on the planet. More recent research has unfortunately proposed that earlier 'findings' of liquid water beneath the surface are inconsistent with corroborated data, and are most likely deposits of volcanic stone, as seen elsewhere on the planet's surface (Grima et al. 2022).

Given the proper preparation work and research, it should be fairly easy to navigate these drastically differing conditions and find reasonable areas in which explorers might settle.



DWG 2_3 *Ground Plane sections through various potential surface conditions*

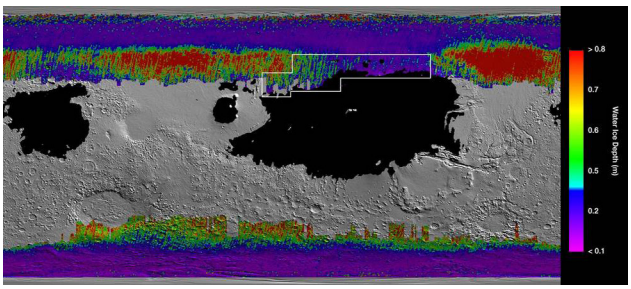


FIG 2_4 Treasure Map for Water Ice on Mars, NASA

Resisting the Elements

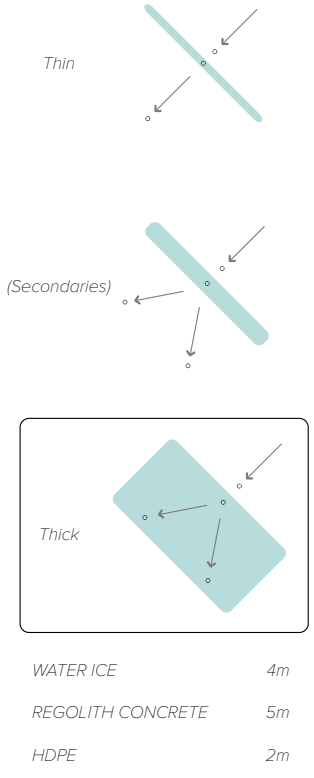
Being knowledgeable of the brutal conditions that we face when visiting Mars is only the first step. To offer a reasonable chance of survival, intense countermeasures must be taken to combat these risks. Luckily, many different teams of researchers have been working on design solutions for these problems both in isolation as well as in holistic experiments. These engineering countermeasures, once mastered, could even become engrained methods of design to sustain life on Mars.

Radiation

Easily the most difficult challenge to overcome, radiation is undetectable to humans without dedicated instrumentation, and its harmful effects are often asymptomatic until it is too late. Beyond Earth's magnetosphere, there are two different types of ionizing radiation to worry about: Solar Energetic Particles (SEPs) and Galactic Cosmic Rays (GCRs). Both cause the same deadly effects to the human body; however, each one acts differently based on its source. Solar Energetic Particles are produced by our sun during inconsistent but identifiable events such as solar flares and coronal mass ejections. But while SEPs come in waves tied to solar events, GCRs are an ever-present rain from interstellar space that fluxes with magnetic field cycles. A habitat on Mars must then offer continual protection from both of these sources if it is to succeed at protecting its inhabitants. (Langford and Bieri 2022)

As Mars does not have its own geomagnetic shield to offer protection, radiation shielding must be an integral part of any habitat design. There are several principles that need to be accounted for when designing one, the most important of those being thickness. No matter what material the shielding is made of it must be thick enough to ensure interaction between the ionizing ray and the atomic structure of the shield. Not only that, but many materials can be separated into secondary particles when struck by ionizing radiation, creating even more consequential radiation than the GCR itself (Dwg. 2_4). The material must be thick enough to contain both the original interaction as well as secondaries. (Rask et al. 2008)

Second to thickness is the material's molecular structure, or more importantly: its density. This is why lead is such an effective material for this task. Launching a sufficient amount of lead into space however is absolutely unfeasible. This means that in order to protect explorers both in space and on the surface of Mars, we must either bring a material light but dense enough to provide adequate protection or find sufficient materials in-situ to build radiation shielding on the surface. Currently there are three materials generally



DWG 2_4 Strategies and Materials for mitigating Solar and Cosmic radiation

accepted as adequate materials for in-situ shield construction: Regolith structures (Llamas, Aplin, and Berthoud 2022, 105517), Water ice (van Ellen and Peck Oct 2018), and High-Density Polyethylene (HDPE) (Shin et al. 2014, 5-9; Sen, Carranza, and Pillay 2010, 582-592).

Of the three, the most accessible shielding material is regolith. It is the most widely available material for this purpose, however due to its relatively low density would require a thickness of several metres to provide comparative protection to Earth's atmosphere. Regolith radiation shielding could be as complicated as 3D-Printed shell structures (Yashar et al. 2019), or as simple as burying a structure beneath metres of loose material.

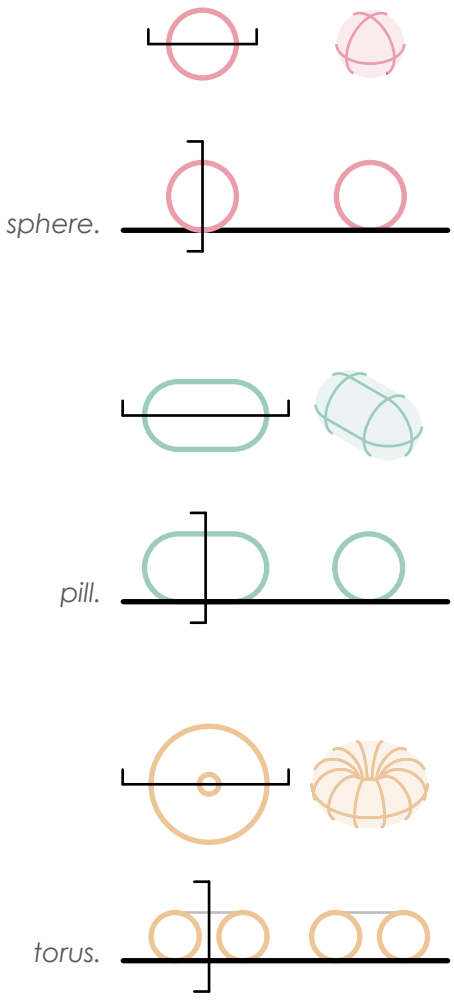
Less accessible but more effective for blocking radiation is water ice. Due to Mars' freezing surface, water ice could be 3D Printed into shells similar to regolith that can be thinner because of its higher density, such as in SEArch+'s *Mars Ice House/Home*. Water could also be stored in a liquid state in large bladders that could offer a dual purpose of radiation protection and storage for life-support purposes (SEArch+ Team and Apis Cor. 2018).

The third, most effective material for shielding against radiation is High-Density Polyethylene. Its molecular structure allows it to be extremely adept at capturing ionizing rays. As well, it is considerably lighter than other shielding materials and would be excellent for structures, however it has one major drawback: it must be produced on Mars. Luckily, the composition Mars means the chemicals required to produce HDPE are abundant, and exact processes are known to produce the material in-situ (Flynn and Rosenberg 2005).

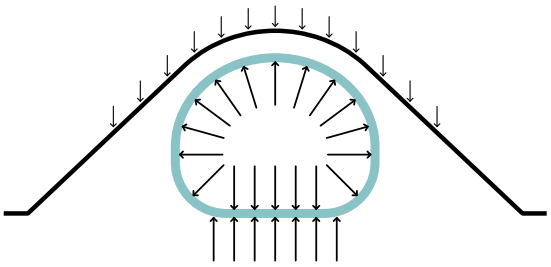
Each of these materials has its own effectiveness against radiation, but also have their own drawbacks. Therefore, a combination of all three must be used based on availability, constructability, and amount of radiation protection required based on the program of each building.

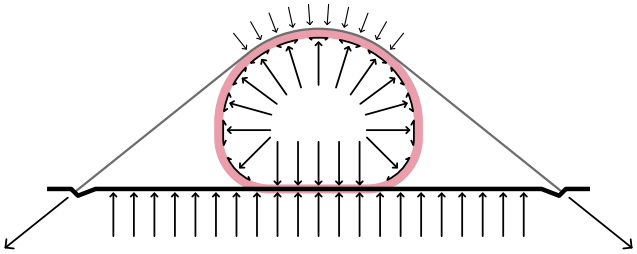
Pressure

All manned vessels brought to or constructed on Mars must be airtight and pressurized. This means suits, rovers, landers, and habitats must be built to withstand significant internal pressurization with little room for failure. To achieve this, a habitat structure must have sufficient tensile or compressive strength (depending on materiality) to withstand the outwards-pushing force. An inflatable tensile structure is optimal for early small-scale habitats as size and weight of Earth-borne cargo is highly limited. However, large-scale in-situ construction must shortly overtake Earth-supplied missions due to the limitations of scale and growth rate, and to influence a quicker move towards independence. This points to two distinctly different typologies: one small-scale based on inflatable technologies driven by pressure forms (pod), and a large-scale typology based on a regular mass structure system (arcade).



DWG 2_5 Possible forms of inflatable objects in low-pressure environments





DWG 2_6 *Squished forms of inflated objects in low-pressure environments*

Pod

The first of these typologies uses mainly a tensile membrane to provide the necessary pressure resistance, in a form designed to distribute forces as evenly as possible across its inner surface. This must be balanced with the ability of this form to be transfigured into usable space for explorers. So, while the optimal form for resisting internal pressure a sphere, much of the inner space would be wasted without a significant increase in scale.

Perhaps a better form to suit both needs might be a pill shape in which the sphere is bisected and extended with a cylinder. This could allow for better use of space both vertically (by creating vertical space for multiple floors) or horizontally (extending the floor area to the length of the pill). This form was heavily researched by SEArch+ and ApisCor in their project *Mars X-House v1* (2019) and will be used throughout this thesis as an effective small-scale solution.

One other possible form that allows for even distribution of internal forces is the torus. In extending a cylinder to connect each end back to each other, a continuous interior space is created that when scaled significantly could create enormous habitats. This typology has been touched on lightly in BIG Architect's *Mars Science City* project as a potential form for large-scale cities (2017).

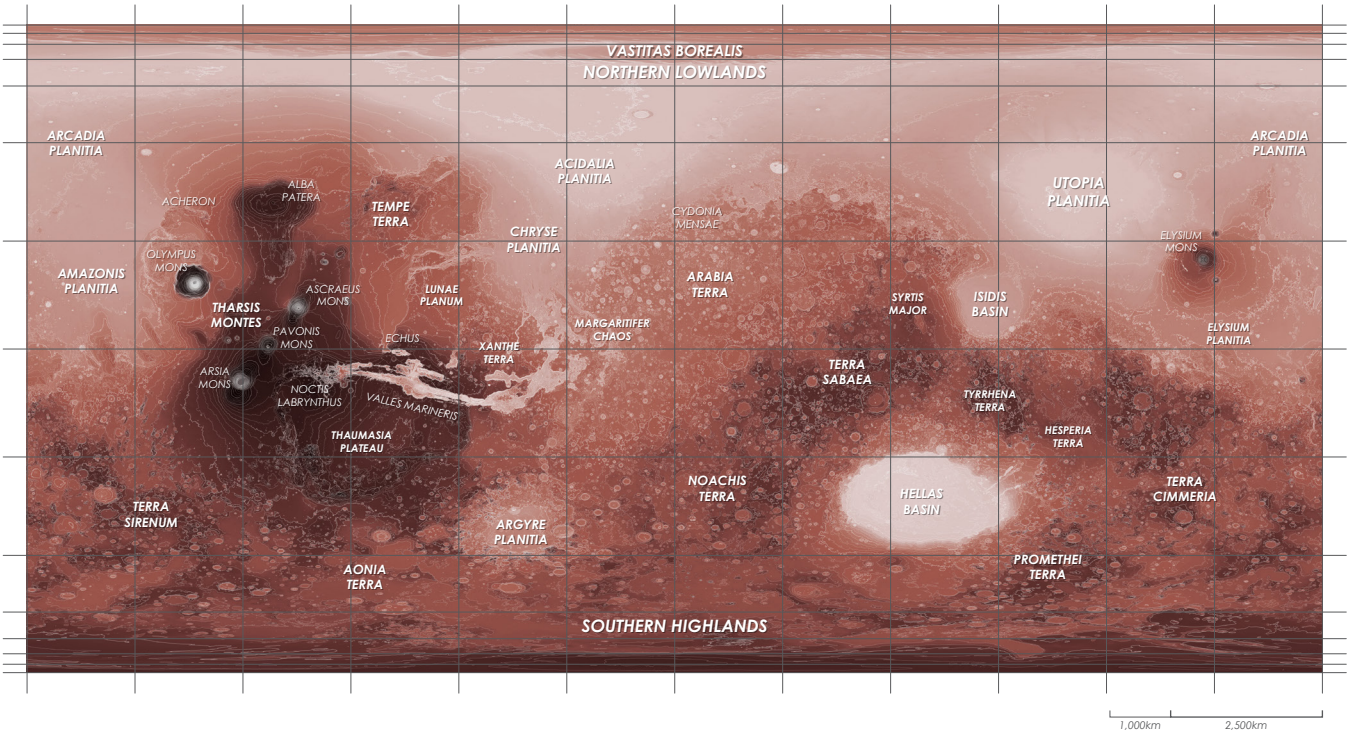
Currently there is no known individual material that can withstand the required pressures to be suitable as a Martian habitat. Therefore, it is likely that inflatables will be made up of more robust composite systems. Internal plastic membranes will provide the required airtightness, while a thicker woven tensile fabric captures forces and transfer them to a stronger tensile cable network. As construction technologies improve over time and the planet's atmosphere is transformed through terraformation, these forms will likely grow enormously in scale and become transparent.

Arcade

Beyond creating inflatable forms, it may also be possible to create habitats that are held together by structural mass. This can be achieved by burying habitats beneath significant amounts of regolith to withstand the outwards pressure, allowing it to consist of walls and flat surfaces (useable space). This points to a typology in which large, regular structures built from cut stone are constructed and buried beneath regolith, simultaneously achieving the goal of radiation shielding. This type of repeating structure can then be built into large continuous living/working spaces at a higher density than the pod typology.

In later generations, these arcades can then be used as foundations for more vertical additions due to their materiality and longevity, and their continuous nature utilized for connection of life-supporting services.

Both of these typologies offer a wildly different formal approach, and thus a different method of organizing space. While the underground arcades host a rectilinear organization spreading out horizontally and vertically, the round nature of the pods lends to a more disordered growth, organizing into larger organic shapes over time. As such, both of these typologies must grow with the population and adapt to the rapidly changing climate, eventually combining into a single urban fabric.



DWG 2_7 Map of Primordial Mars

Terraformation

Before moving on, it is important to understand both the purpose and methods behind the idea of terraformation. Roughly speaking, the goal of terraforming a planet from its existing state (Dwg 2_7) to one that can support Earth-based life (Dwg 2_8). In the case of Mars, that is to thicken and warm its atmosphere to tolerable levels, reconfigure its atmospheric composition to suit oxygen-breathing life, bring liquid water to the surface and create fertile soil allowing extensive plant growth. Each of these is a Herculean task on its own, but combined they are necessary to make Mars a viable home.

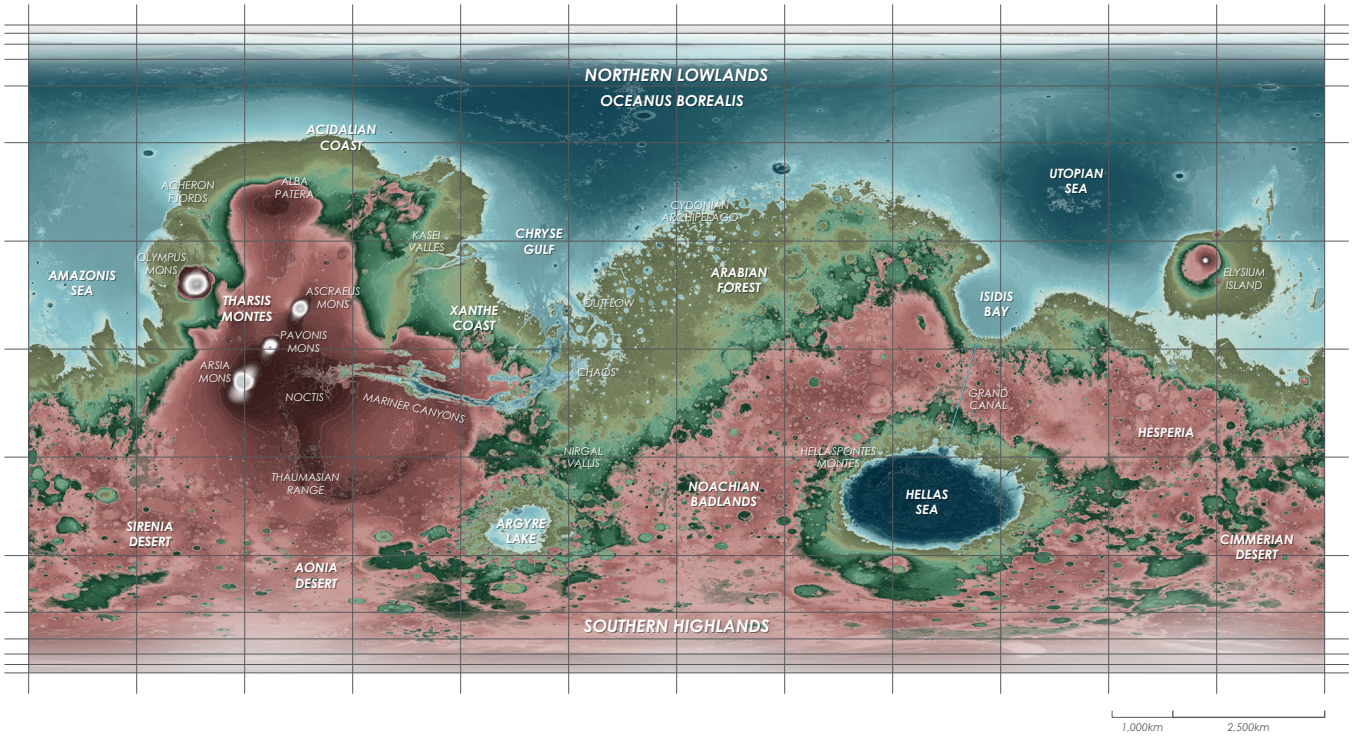
As far as human projects go, terraforming Mars will be the largest cooperative undertaking our species has ever attempted, in both physical and temporal scales. Those who begin this project will not live to see out its completion, and its unlikely their great-grandchildren would either; it's a process that takes hundreds if not thousands of years. This thesis project estimates a time scale of roughly 400 years for significant transformation of the atmosphere and reintroduction of oceans, however full terraformation of the soil is a process that could take thousands of years to build and rebuild in recursive cycles of life and decay.

The first steps to terraformation involve finding ways to add gases (particularly nitrogen and oxygen) and heat to the atmosphere. One often proposed idea is to detonate nuclear explosives on the polar caps of the planet to vaporize water and thicken the atmosphere while simultaneously adding enormous amounts of heat. Unfortunately, this would leave the planet uninhabitable to anyone for centuries. More subtle ideas include digging deep holes in the crust to create updrafts of geothermal heat, aerobraking redirected ice asteroids in the atmosphere, or installing massive orbital mirror systems to amplify the sun's light.

As for water, recreation of Martian oceans relies heavily on the uncertain existence of an underground water system. If nonexistent, Mars oceans would require the additional water of many ice asteroids. In the case that there is enough water though, Mars' lowest elevations (mainly northern hemisphere) would become its oceans and seas; the Vastitas Borealis transformed into a great northern ocean, Hellas Basin a sea, and wide bands of vegetation wrapping the edges. Due to the small size of Mars and large variation in its surface height, it is unlikely that the accrued atmosphere will retain significant density in its higher altitudes, leaving large areas of the lower hemisphere untouched by the planet wide changes.

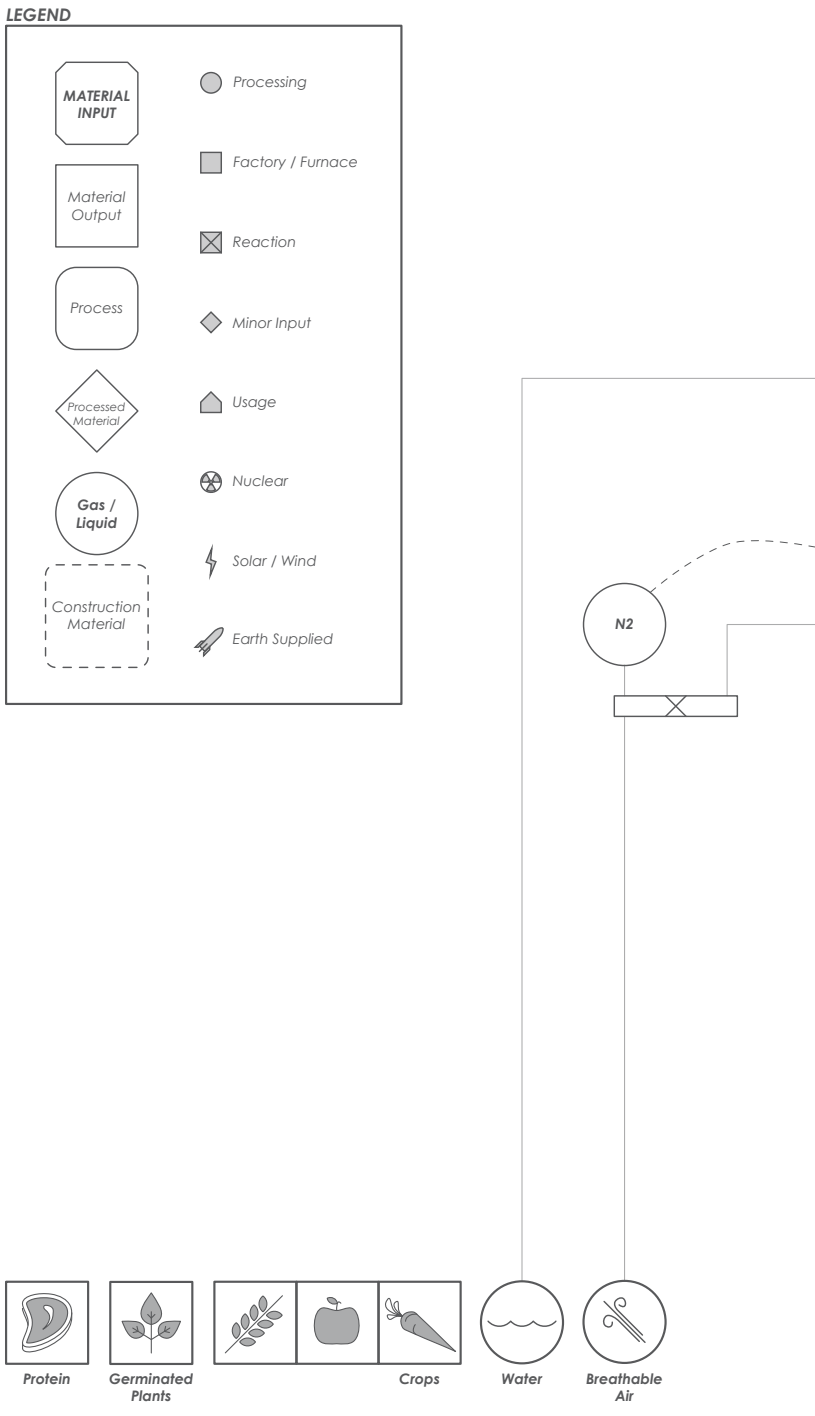
On the ethics of terraformation, the question is begged whether or not humans have a right to alter such a primordial object as Mars. Perhaps best played out in science fiction, this thesis will assume a general agreement on a limited but livable terraformation, as laid out in Kim Stanley Robinson's *Mars Trilogy* (1993-96).

If undertaken, terraforming the planet will have a significant impact on human (or post-human) life, and as a result the cities we create. They will be required to continuously grow and adapt to a shifting atmosphere and as a result will display a rich palimpsest of resilience and growth.



DWG 2_8 Map of Terraformed Mars

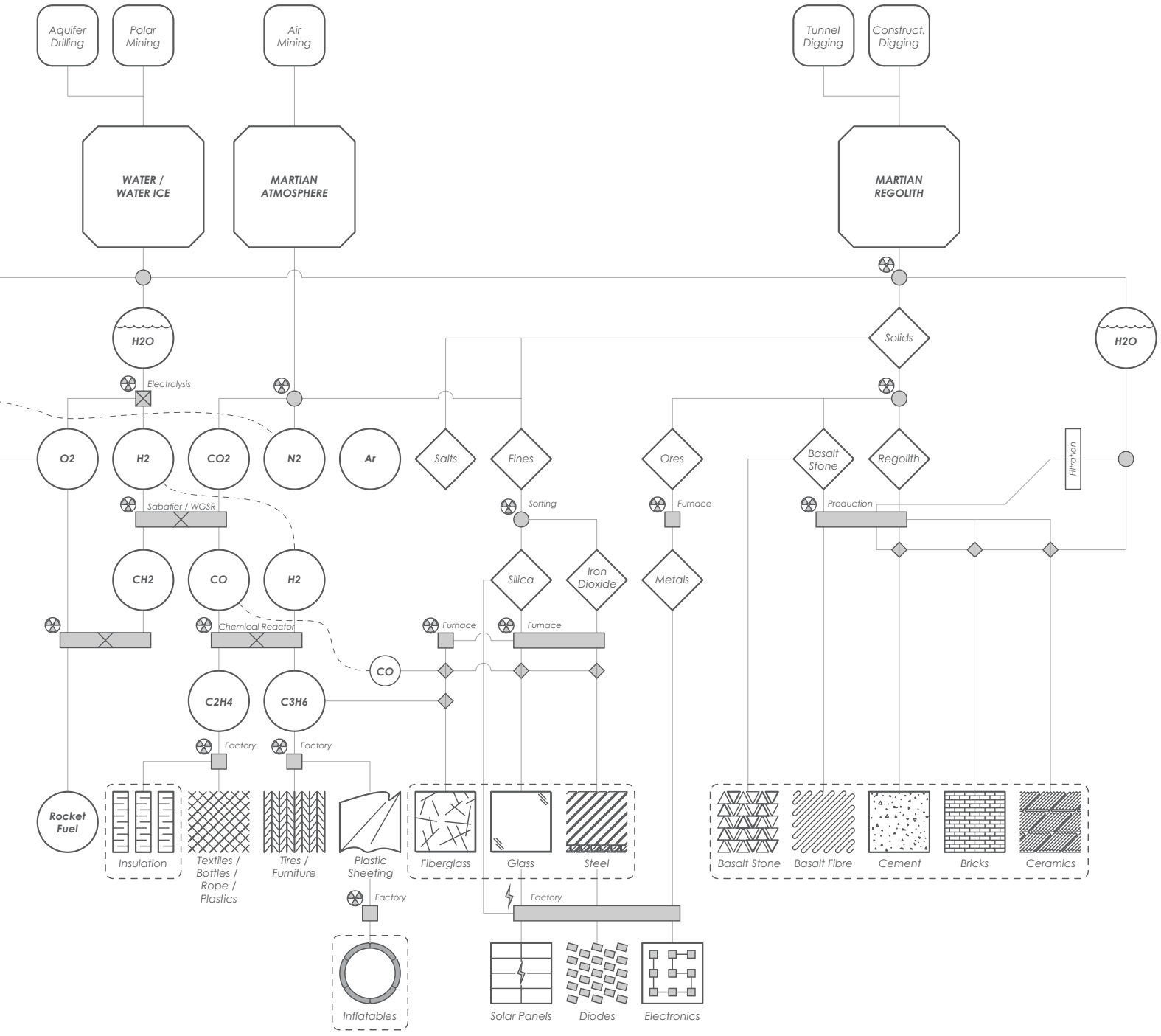
DWG 2_9 Systems / Material Flow Diagram



Material Flow

Extensive industrial systems must be constructed on Mars to achieve an expedient independence from Earth. They must be placed in coordination with the required material inputs, and therefore have a strong influence on the location of early settlements. As the planet is terraformed however and global infrastructure becomes more commonplace, site selection can vary beyond reliance on these energy intensive processes.

On the other hand, there is a set of systems that are integral to the function of a settlement or city: power, air, water, and food production. These are systems of life support, and the success of a civic life depends on their seamless integration into a settlement's infrastructure. Each of these systems will be expanded in detail within later design explorations.


Aquifer Drilling
Polar Mining
Air Mining
Tunnel Digging
Construct. Digging
WATER / WATER ICE
MARTIAN ATMOSPHERE
MARTIAN REGOLITH
H2O
Solids
H2O
Electrolysis
O2
H2
CO2
N2
Ar
Salts
Fines
Ores
Basalt Stone
Regolith
Filtration
Sabatier / WGSR
Sorting
Furnace
Production
CH2
CO
H2
Silica
Iron Dioxide
Metals
Chemical Reactor
Furnace
Furnace
CO
C2H4
C3H6
Factory
Factory
Rocket Fuel
Insulation
Textiles / Bottles / Rope / Plastics
Tires / Furniture
Plastic Sheeting
Fiberglass
Glass
Steel
Basalt Stone
Basalt Fibre
Cement
Bricks
Ceramics
Factory
Factory
Inflatables
Solar Panels
Diodes
Electronics

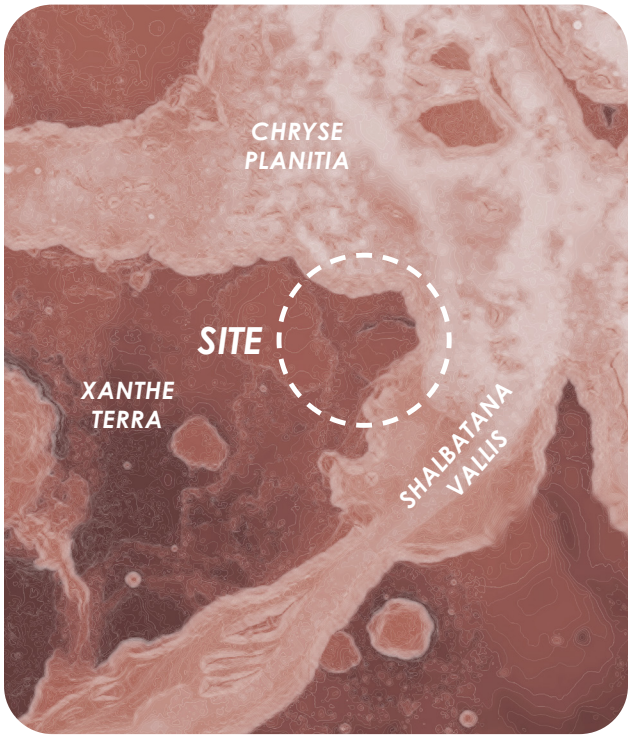
Site Selection

Given all the necessary factors required for survival, selecting an exploration zone will be no easy task. However, as this thesis explores the development of cities along a significant time scale, other factors must also be taken into account such as landscape elements, or its position on a terraformed Mars.

As the planet changes with added atmosphere and surface water, the usage of the landscape will shift; low elevations will become seas, barren plains transformed into green forests, mountains into islands. Therefore, a chosen site must be in a position to survive these drastic changes: high enough in elevation to avoid being buried under a future sea, but not so high that it escapes the atmospheric changes, and near enough to the equator to ensure adequate temperatures and sunlight year-round.

Combining all of the relevant data regarding material supply and contrasting it against elevation maps of the Martian surface, several sites appear as significant. Some of these options include significant geological features such as Acheron Fossae, Kasei Vallis, Nilo Syrtis, or Echus Chasma, and it is likely that over time, villages will spring up around the red globe, growing into cities and inhabiting every type of terrain. For the purposes of this thesis however, Shalbatana Vallis suited the criteria not only in engineering value, but also through its position within a future terraformed Mars as a coastal city. As well, it was the first direct evidence of an ancient shoreline (Baker 1982), contributing further to the mythology of this future city's formation.

With a site chosen, application of the researched engineering technologies can begin, which will hopefully lead to an understanding of how a Martian res publica is formed.



DWG 2_10 Primordial Map of Shalbatana Vallis

DWG 2_11 Terraformed Map of Shalbatana Vallis

Systems of Urban Growth *03*

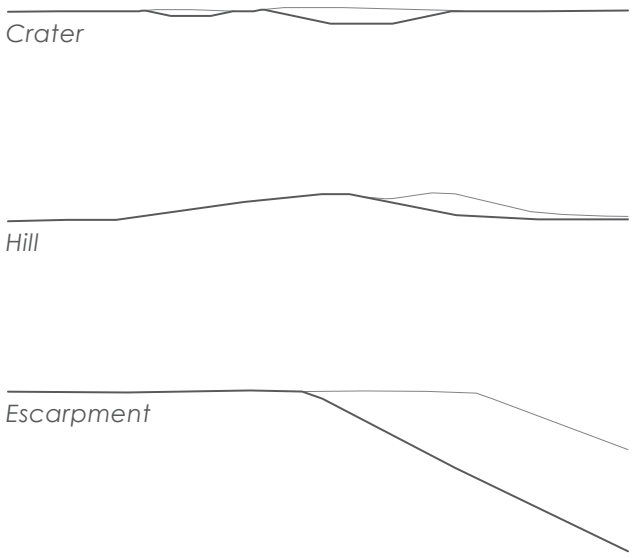
The first portion of this design process was intended to examine the site at a larger scale and context over the timespan of terraformation. Taking place over the course of several centuries, this examination views a snapshot at three key stages of terraformation.

Two Typologies

On the selected site, three landscape features stand out: a set of two craters, a ridge of low hills, all surrounded by a steep escarpment. On a basic level, each of these consists of plains and slopes at various angles, leading to the emergence of two typologies. To best provide shelter from the raw elements, each must employ a different engineering strategy.

Habitats on flat plains can be constructed from an inflatable pod that provides a pressurized living zone. They can then be sheltered beneath a 3D printed regolith concrete shell for radiation protection. Due to their round shape, organization is more random and organic, using strategies of close packing to reduce exterior exposure.

In contrast, slopes can be terraced to create large, arcuate structures built from heavy stone. They can then be buried beneath more regolith to resist the internal pressures and negate radiation. The arcade's strict radial organization and simple redundancy provides density of program that could allow reasonable increases in population.



DWG 3_1 Key Sections of Shalbatana Vallis

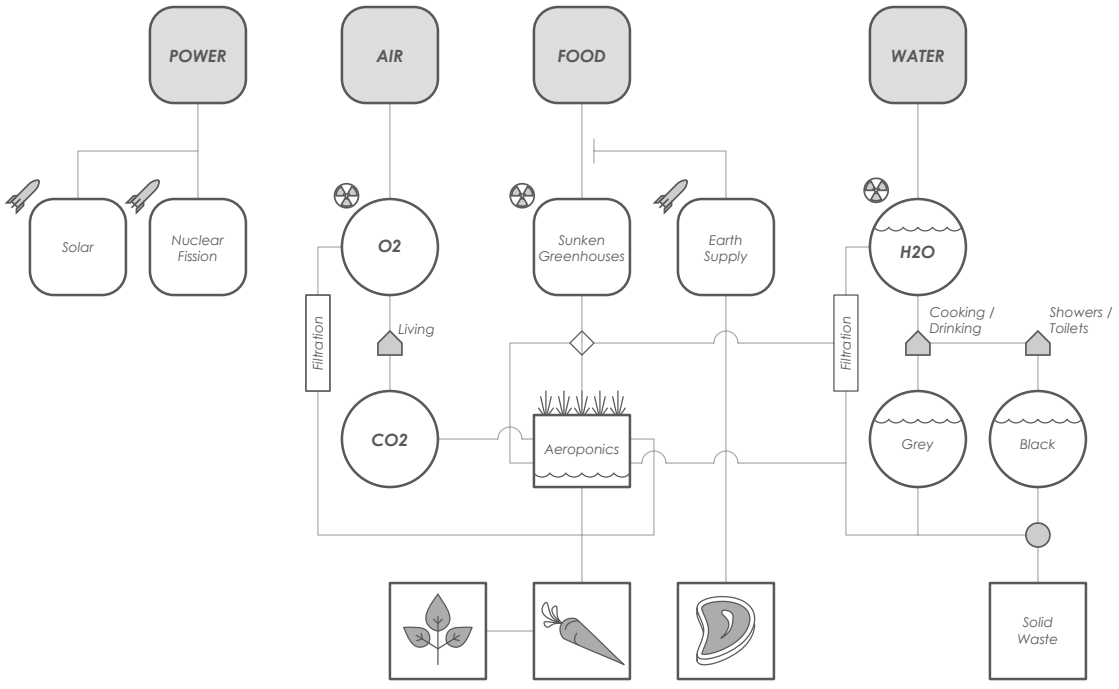
Martian Year 18

The first generations of Martian settlements will be based heavily on constructing shelter for survival, with little room for error. Even if terraformation processes had begun, there would be no significant changes in the atmosphere at this time scale. Early settlements will still be heavily reliant on Earth-based supply missions, but a strong early push to build necessary infrastructure would kickstart the transition to independence.

Life support systems at this stage will remain relatively straightforward, with the biggest advances made in food production. Long, continuous tunnels integrated beneath the arcade will provide extensive area shielded from radiation to grow a continuously expanding food supply. Power supply will likely come from small-scale localized nuclear fission reactors, supplemented with a small amount of solar.

DWG 3_2 MY18 Textured Site Plan

DWG 3_3 MY18 Systems Flow Diagram



Crater

A pair of craters, the largest spanning over a kilometer across sit central upon the plateau. Dawning the names of Psyche (goddess of the Soul) and her lover Eros (god of desire, and son of Aphrodite), this mythos inspires a stewardship of life in an otherwise raw and desolate Mars (Ares).

The first habitats, autonomously 3D printed shells from in-situ regolith concrete will be constructed close to these craters in preparation for larger construction projects. As the population increases through immigration and natural birth, these lone pods will be unable to support a larger protected population due to their exposure.

Craters, as continuous circular slopes then become an optimal place to build large, terraced stone structures for a growing population. Heavily focusing on protection and infrastructure, they seek to create a consistent food source to supply both its own population and the growing regions around it, using an integrated system of greenhouse tunnels.

An immense stairway feature entitled the 'Odeon' cuts through the largest terraces, connecting each level at grade and providing a centralizing feature for circulation.

Successful implementation of this infrastructure could then support extended growth of the Grovelands into their own sprawling communities.

Hill

A ridge of hills runs East-West separating the Northern edge of the plateau from lower flatlands. Its two peaks survey a full view of the surrounding landscape, and as such would be claimed as a sacred space.

Given Mars' unfathomable distance from Earth and its scrutinous scientific population, early Martians create a pseudo-religion in reverence to the spirit of Mars itself. Adopted from KSR's Mars Trilogy, Ka (taken from the Japanese words Kasei meaning 'fire-star') represents this primordial Martian spirit. As such, this temple becomes a space to enact the rituals of death and burial. Differing from Earth, the simple burial or cremation of a body would be deemed wasteful. Seen not as loss, death on Mars is an offering of one's internal biome to the creation of a larger ecosphere.

More practically speaking, the hill itself acts as a natural barrier between the debris of a launch/landing site and any inhabitable spaces. And although effective, a substantial blast wall is constructed to aid in the mitigation of damage from rocket use.

Across the hill, a scientific community inhabits the low slopes in a terrace structure, focusing on research and development of soil microbiomes.

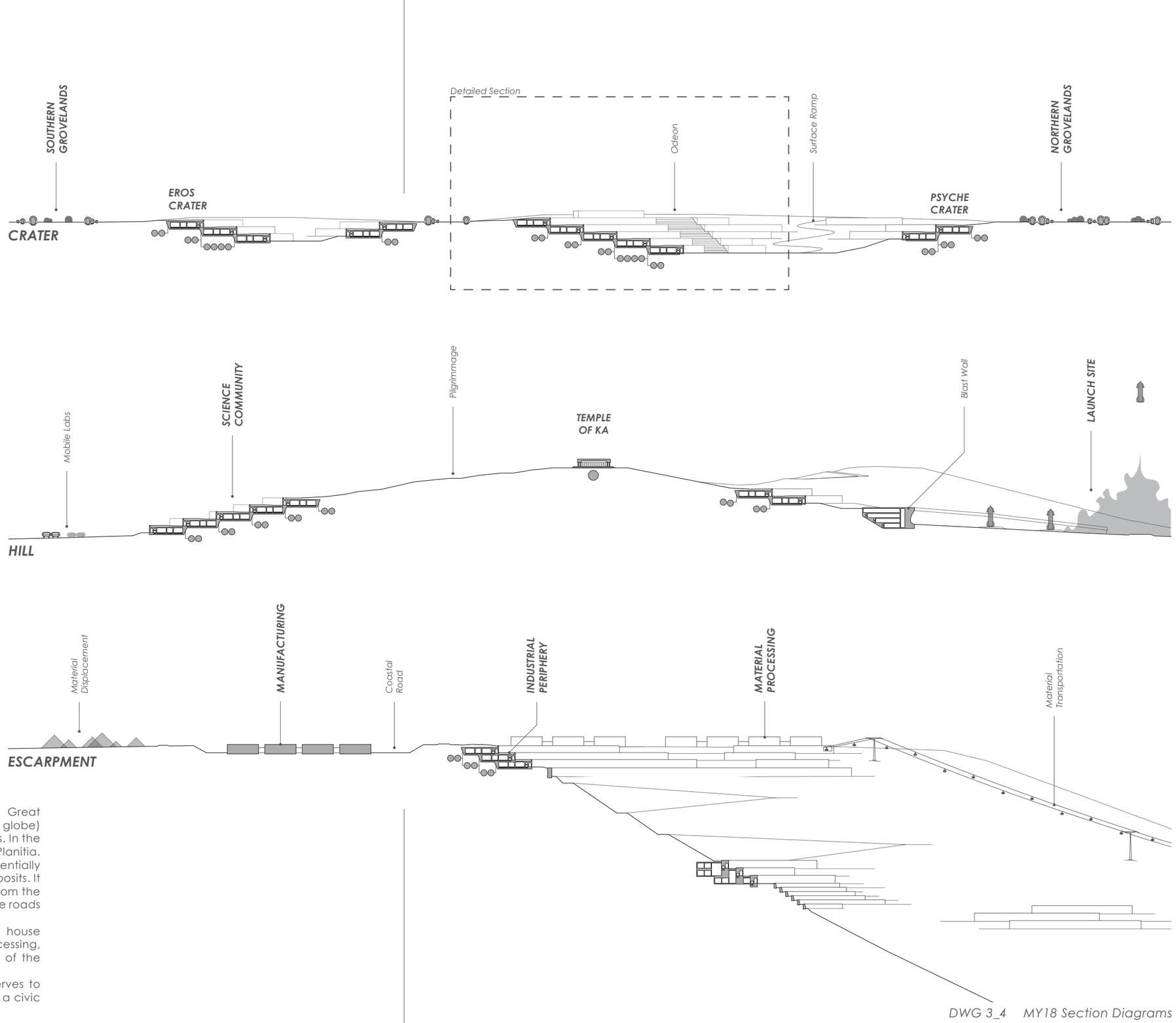
Escarpment

Surrounding the plateau to the North and East, The Great Escarpment (an extreme elevation difference encircling the globe) separates the Southern Highlands from the Northern lowlands. In the case of this site, Xanthe Terra drops over 1600m into Chryse Planitia.

Due to its geological history, the escarpment could potentially offer relatively easy access to necessary mineral and ore deposits. It then becomes a prime location to not only bring materials from the floor of the basin but out of the escarpment itself using surface roads and cable transportation.

Large linear spaces could then be constructed to house extensively automated industrial systems and material processing, enabling consistent growth in the more populated regions of the site.

Terraces also line the coast; however, their purpose serves to supplement the industrial infrastructure rather than to house a civic population.



DWG 3_4 MY18 Section Diagrams

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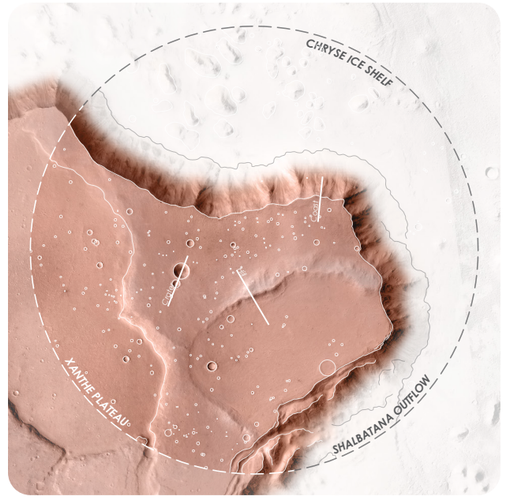
Martian Year 83

On the cusp of nearly a Martian century into colonization, terraformation of the planet will have begun to exhibit significant changes. An atmosphere thickened and heated by the aerobraking of thousands of asteroids now provides insulation in terms of radiation and heat. Aquifers emptied onto the surface now cover the northern landscape with a thick layer of water ice.

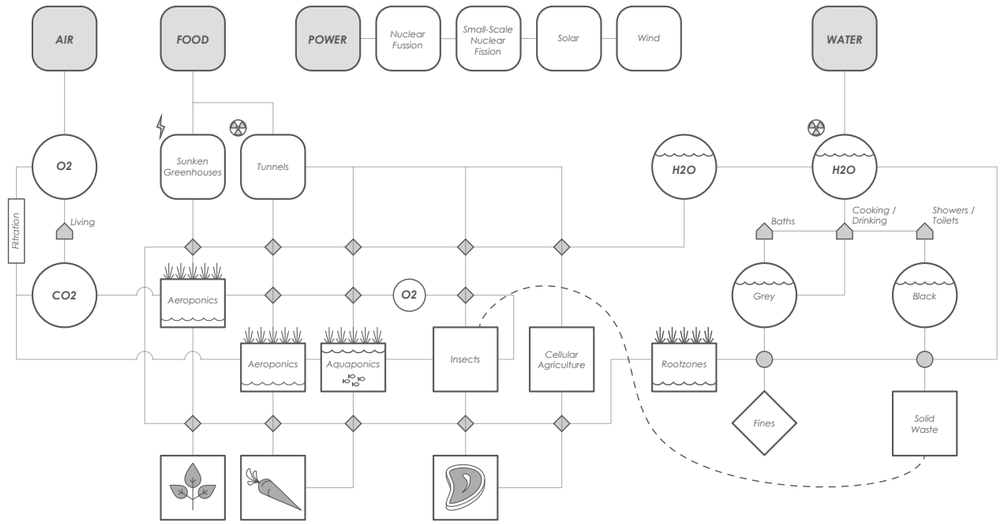
It is likely that the composition of air will still be unbreathable by humans, and exterior pressures could still yield minor injury. Some humans however have begun to adapt to the Martian atmosphere either naturally or artificially. These new natives thus issue in a general comfortability and mastery of the landscape. Surface plants are minimal, and only engineered forms of lichen, moss, and algae flourish as full transformation of the soil will take considerably longer than the air.

Along with advances in construction technology, the changes in atmosphere issue in a new architectural typology: the bubble. Advances in lightweight structural and insulative technologies combined with Mars' lower specific gravity allow for the creation of large, transparent domes.



DWG 3_5 MY83 Textured Site Plan

DWG 3_6 MY83 Systems Flow Diagram



Crater

The craters, being the largest aggregation of infrastructure and thus population sees the most extensive development. The introduction of bubbles into both the Grovelands and crates allows for a much denser surface population.

Building upon the extensive structure of the earlier arcades, a large continuous foundation is constructed around each crater to anchor the new bubbles - the 'Outer Rim'. Within each, construction on a series of 3-5 storey mixed-use buildings are constructed using the most substantial parts of the arcade structure as a foundation. Constructed from lighter materials such as magnesium alloys and previously wasted salts, these buildings tap into the arcade's life support structure and vertical circulation. Each terrace offers varied public function at grade, while private program and urban farming begin to occupy the upper levels, thanks to the significant reduction in radiation levels. Between these boulevards, a variety of flora is planted to bring life to the public realm, and surrounding the Odeon, buildings and parks transform it into an integral public space.

At the center of Psyche, water is collected into a shallow lake, being pumped from the upper levels down through a rough surface watershed.

A select few of the tunnels will likely be repurposed for intracity passenger travel, connecting both craters to their surroundings through underground railways.

Around the craters, the slow growth of single pods into self-organized rings allows for the enclosure of their courtyards using insulated domes. Forming into a continuous foam-like pattern, pods are then separated by size into public or private program, or greenhousing.

Hill

Due in part to developments in space-travel technology, it is unlikely that humans will continue to launch rockets in a similar manner due to inefficiencies and is replaced by an electromagnetic rail launch. This becomes the city's central location for international travel, connecting directly to its underground transit system.

The temple, still used as a center for ritual decomposition is extended to pay homage to the human mythos surrounding the city. A temple for Ares (Mars) is constructed on the Eastern peak, overlooking the city and Shalbatana Vallis. In addition to the Temple of Ka, a temple for Aphrodite is constructed between Ares and Eros (her son) mediating the relationship between the destructive masculine power of primordial Mars and the steward-like love offered through the act of terraformation.

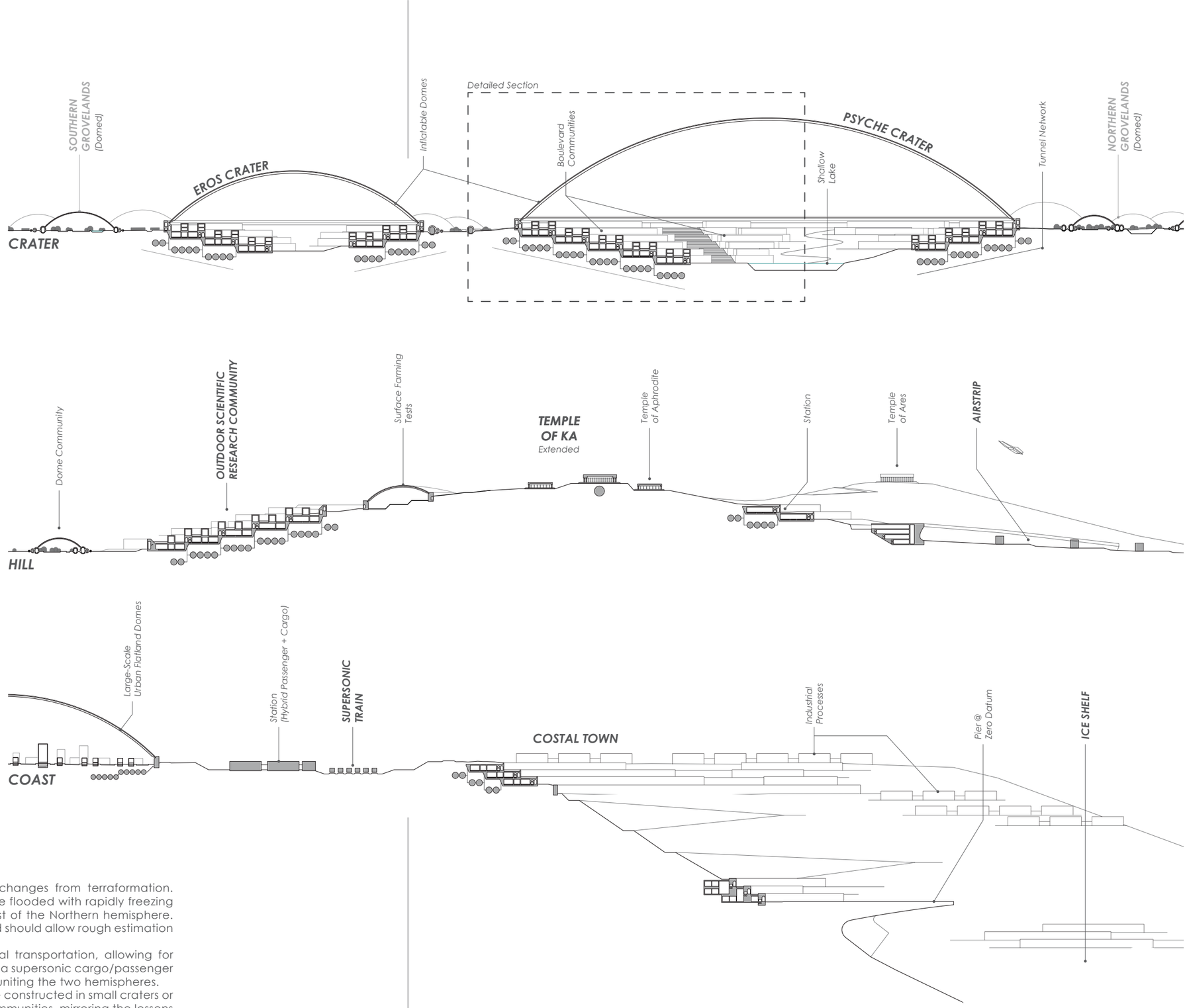
Meanwhile, smaller dome communities pop up surrounding each terrace structure. The scientific research community begins tests into large-scale crop farming, while making attempts at becoming the first truly 'outdoor' space on Mars.

Escarpment

The Great Escarpment sees the greatest landscape changes from terraformation. Release of underground aquifers causes low elevations to be flooded with rapidly freezing water, eventually forming a large mass of ice covering most of the Northern hemisphere. Careful calculation as to the exact amount of water released should allow rough estimation of the final zero datum (future sea level).

This ice shelf will likely be used as a method of global transportation, allowing for connection of all cities located near coastal edges. On land, a supersonic cargo/passenger train is constructed for long-distance transportation, further uniting the two hemispheres.

Inland from the coast, new large-scale bubbles might be constructed in small craters or even on flat land, each containing their own functioning communities, mirroring the lessons learnt from Psyche and Eros.



DWG 3_7 MY83 Section Diagrams

Adopted first by the smaller pod communities, these surface pods begin clustering into round, organic formations. Acting as a foam, completed rings are then bubbled to create a semi-outdoors 'courtyard-like' space - the Grovelands.

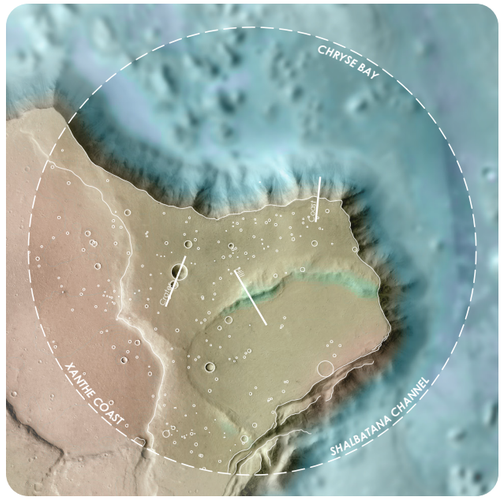
Around the craters, new foundations are built to anchor immense domes, enclosing both existing and added infrastructure. This bubbling allows for further expansion upwards and an extension of accessible space, releasing inhabitants from the bounds of their underground structures and onto the 'surface'.

Systems, still relying on early-built infrastructure, will advance to include more self-sufficient forms of food production, integrating water and air cycles in constant renewal. As well, advances into nuclear power might provide a fusion solution, supplementing the solar and wind renewables in place.

Martian Year 216

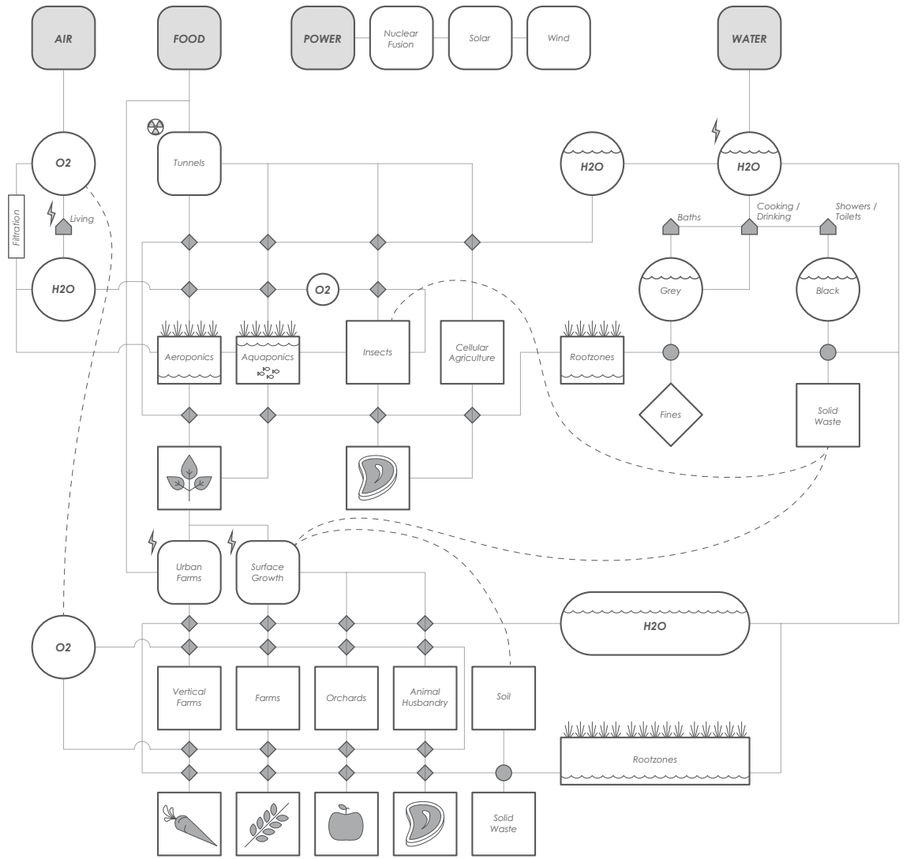
At this stage in terraformation, the atmosphere will have been altered significantly, both in composition and density. And although still much cooler and thinner than Earth's, surface life can now be supported at a substantial level.

The ambient temperature, now exceeding 0°C, in combination with existent geothermal heat allows for the warming of the Northern ice shelf, transforming it into a vast ocean. Wind currents carry moisture and engineered seeds to hydrate and spark the creation of new biozones. This spread of greenery allows for the introduction of wood as a construction material, with new forests being stewarded into maturity.



DWG 3_8 MY216 Textured Site Plan

DWG 3_9 MY216 Systems Flow Diagram



Crater

The craters and Grovelands, given their heavily agricultural program, retain their domes despite the newly hospitable atmosphere. Unfortunately, this thicker atmosphere generates much more severe dust storms, and any substantial deposit of iron oxide could bury an entire crop yield. The domes protect against these unavoidable dust storms while also retaining the benefits of a controlled environment, allowing optimal plant growth.

Eros crater could potentially house an indoor forest, creating a constant supply of wood as a building material. With this progression, extensions and towers built onto existing boulevard buildings are constructed to increase both population density and urban farming capacity. Parks have matured and an extensive watershed cycles water throughout the city, its carefully crafted rootzones, and into a central lake teeming with life.

A connection is added between the domes of Psyche and Eros, allowing at-grade pedestrian connection, and integrating the Odeon to create a central public space.

The Grovelands continue to expand outwards, connected internally through the foam network, and externally through discreet surface roads. Expanding towards the Outer Rim of the craters, the foam collides with the large domes, deconstructing its foundation wall and creating direct connections between the craters and their surrounding groves.

Hill

With the planet's globalization and population increases, ritual acts surrounding death and decomposition become the norm, decentralizing the practice from the temple. As such, the sacred space left derelict falls to its green surroundings. Centuries of biome reconstitution has left the hill's soil rich, and the temple is transformed into the Sacred Grove. A constant reminder of the sacrifices made by generations to bring life to this arid planet.

Long distance travel (now taken over by high-speed train), alongside traditional space travel (now replaced by space elevators), are shifted and removed from the site. The unused blast wall now becomes a museum displaying the long arduous journey of humankind's spread into the solar system

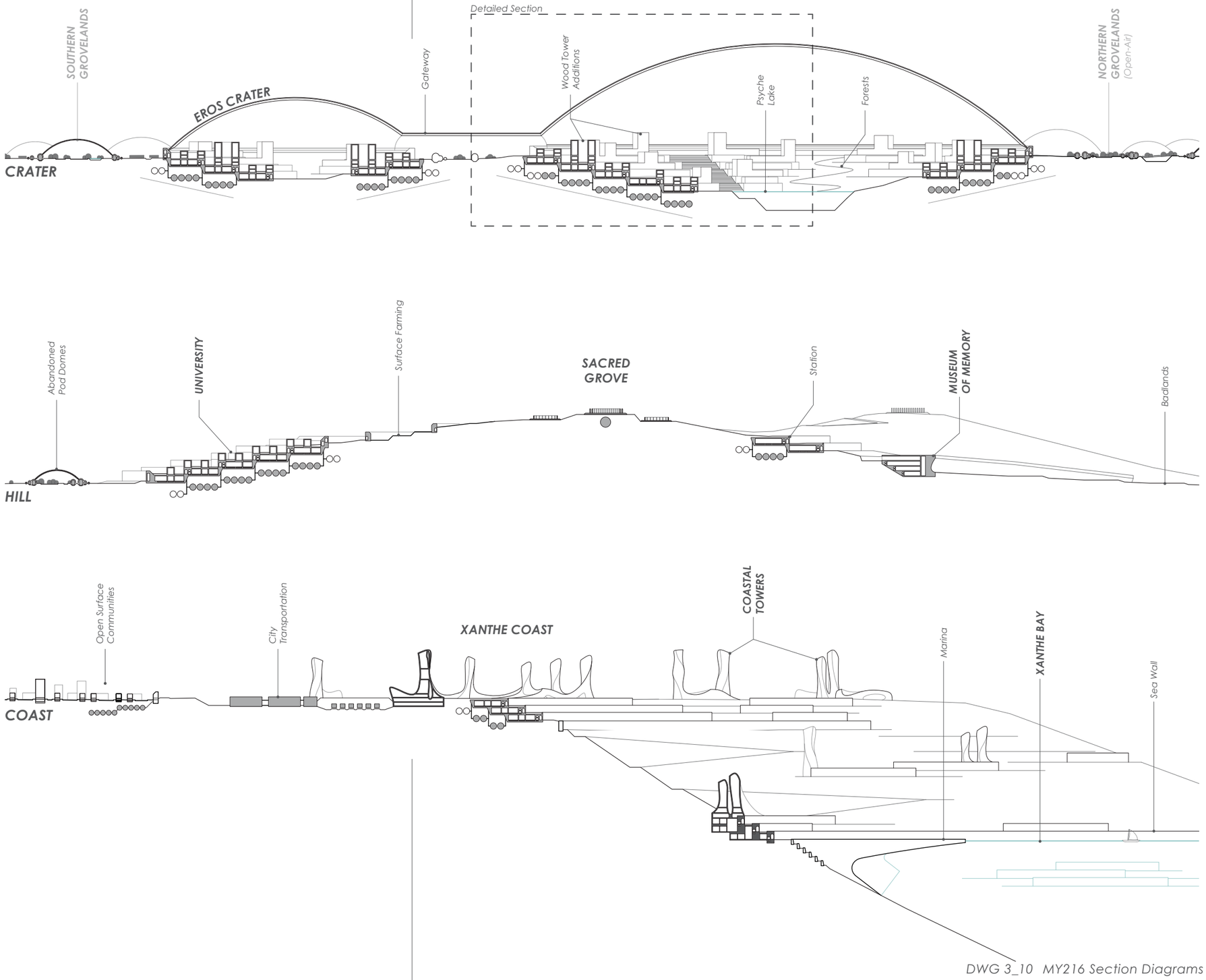
Meanwhile, the scientific community, once the first to transition to an exterior community is reprogrammed into a university, connecting education to this culturally significant site.

Escarpment

The melting of the Chryse ice shelf into a deep sea begins to reshape the populations' trajectory altogether. Due to its newfound connectivity by water, the Coast sees the greatest development in economy, becoming a center of global trade for the city.

This sudden growth fuels a reshaping of the rigid industrial land from one of manufacturing to one of commerce and livelihood. Blue waters crash into the newly built seawall as strong winds draw in a crowd of sailors and windsurfers.

In turn, a new outdoor typology is crafted: windswept towers reminiscent of the wind hewn ventifacts of primordial Mars stand out from podiums like the ever-shifting barchans. Continuous megastructures line the coast, creating a wide variety of live/work/play program. This newly found coastal culture inevitably contrasts the existing agricultural mindset of the crater community, however Mars' pluralistic nature will always allow for this coexistence to flourish.



DWG 3_10 MY216 Section Diagrams

As surface life becomes more commonplace, structures not limited by the intense radiation or pressure differences are constructed, and new typologies emerge. These new forms greatly contrast the functional design of existing structures, and value significant architectural merit beyond strict function. As an unfortunate side effect, this newfound freedom of location slows development near Shalbatana Vallis, as new cities and methods of living are founded across the dramatically altered globe.

Food systems, still an integral part of the urban fabric expand to include local surface farming, tree orchards, large urban farms, and animal husbandry. Within the crater/foam network, surface watersheds renew both air and water through designed rootzones, transitioning the previously artificial life-support systems to a natural, cyclical process.

Large-scale nuclear fusion reactors power the globe across vast distances, however smaller independent towns continue to use renewables for their limited needs.

A society grows great when old men plant trees in whose shade they shall never sit.
Greek Proverb

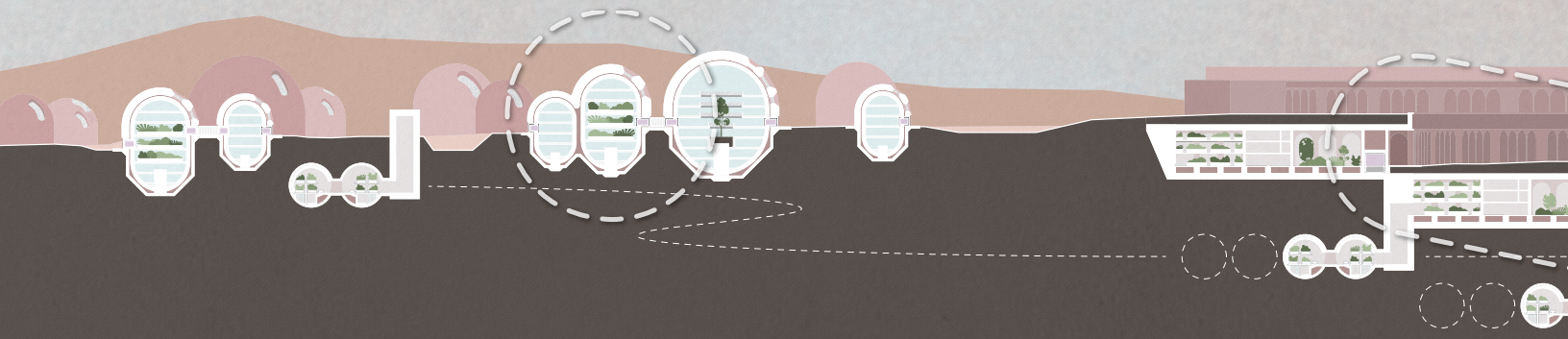
The Martian Res Publica *04*

The final portion of design seeks to closely examine the development of the crater and its typologies over the course of terraformation. In doing this, I hoped to expand on exactly how the original environmental factors shaped the form and layout of each typology, and how each grew and evolved to adapt the changes of terraformation. Finally, I created a plan of the two craters in their 'terraformed' state that embodies the detailed progression of the sectional explorations.

In performing this series of examinations, I hoped to exhibit the continuous growth of a settlement into a city, and how the combination of engineering challenges, environmental changes, and mythos combined to create uniquely identifiable Martian res publica.

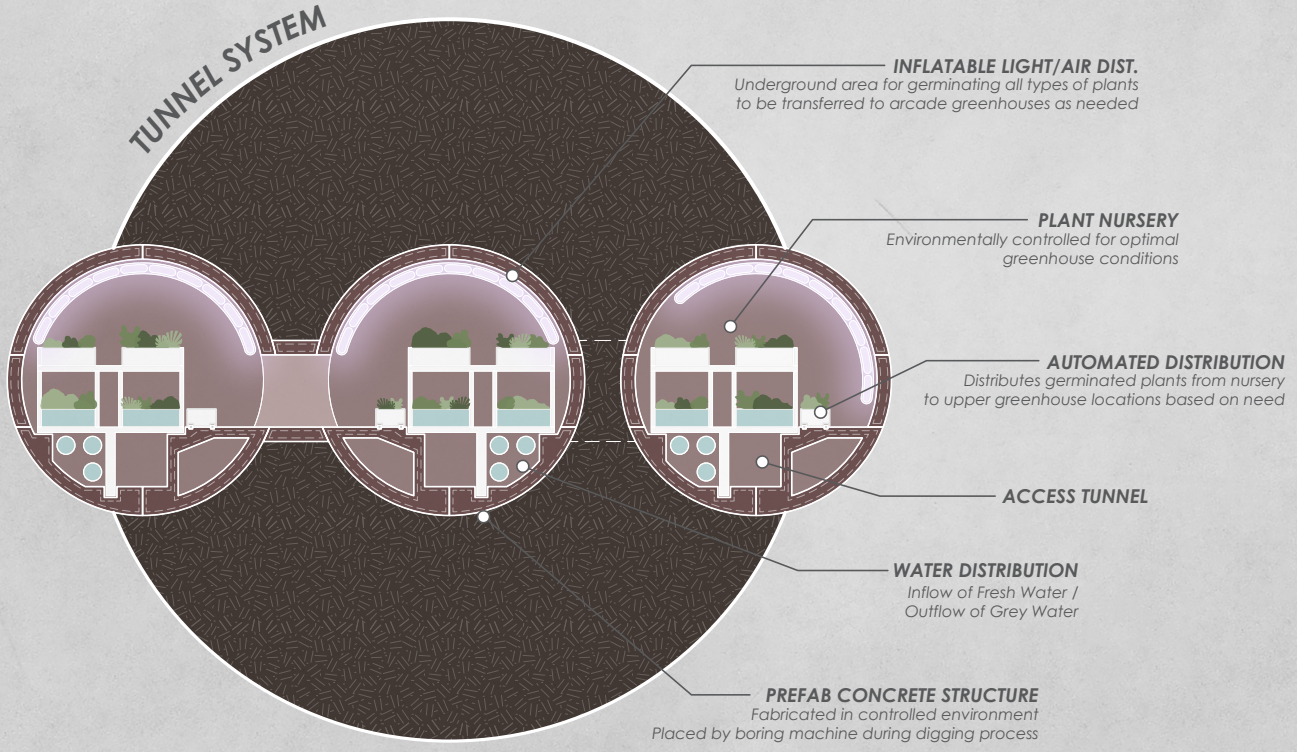
YEAR 18

Earth Year	*34*
Planet Population	*13,200*
City Population	*752*
Avg. Surface Temp.	*- 81°C*

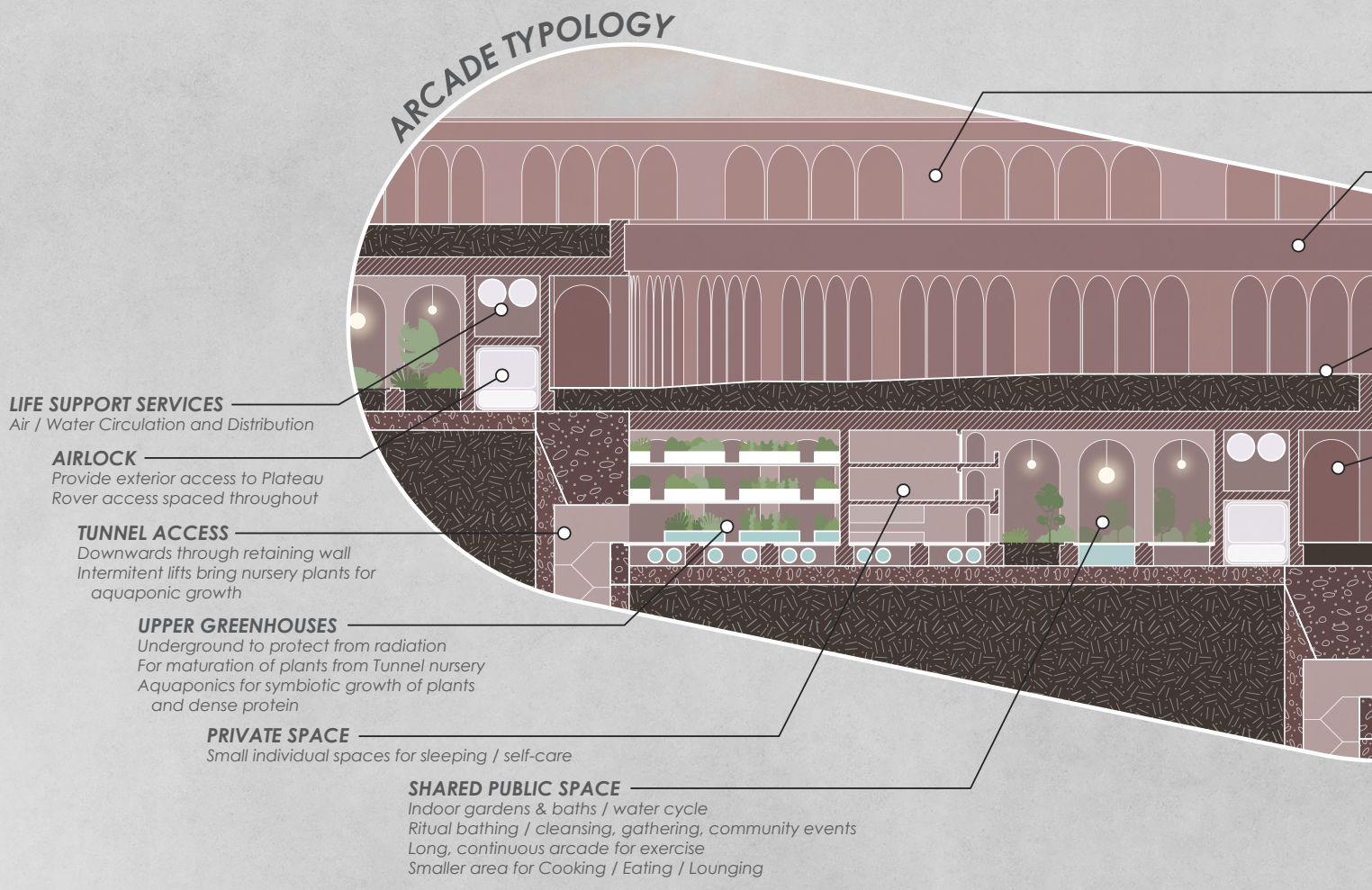


DWG 4_1 MY18 Crater Section

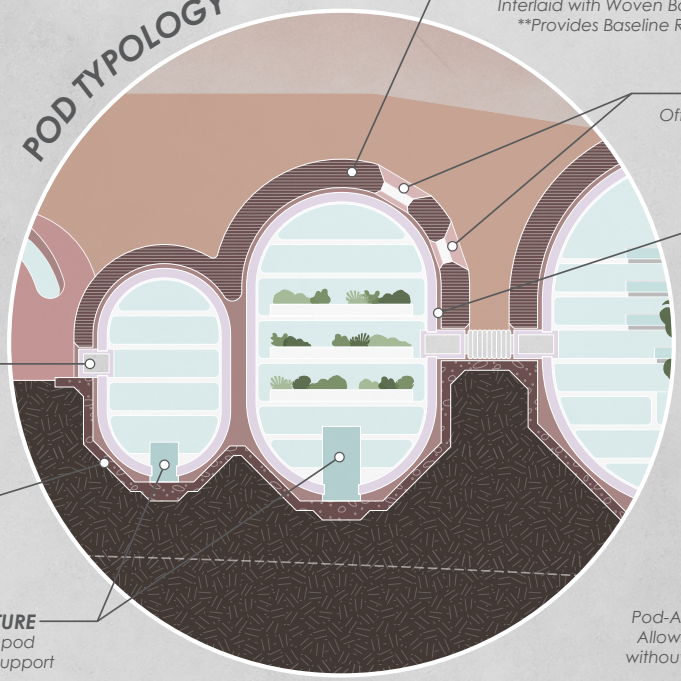
PSYCHE



DWG 4_2 Blowup | Tunnel Systems



DWG 4_3 Blowup | Arcade Typology



3D PRINTED REGOLITH SHIELD
Robitically / Autonomously printed
Interlaid with Woven Basalt Reinforcement
***Provides Baseline Radiation Protection*

HDPE WINDOWS
Offers some radiation protection while allowing views of the exterior landscape and sky

INFLATABLE MEMBRANE
Layered with pressure reinforcement / Insulative pockets. Circulates air and provides heat at interior surface

AIRLOCK
Provides exterior access and connection to adjacent pods

PRIVATE (Sm.)
Small scale pods for private activites
Sleeping, small scale cooking/eating
Individual research

C.I.P. CONCRETE FOUNDATION
Basalt Fibre Reinforcement

PUBLIC (Lg.)
Largest pods - Intended for group use
Working / Research, Exercise, Community Meals, Socializing, Relaxing

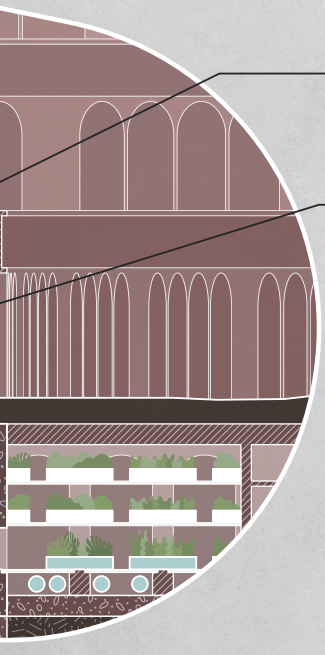
GREENHOUSE (Med.)
Pod-Accessible, localised greenhouses
Allows pods to retain food sovereignty without syphoning off the Crater system

CENTRAL STRUCTURE
Base for inflation of pod
Connection to life support

DWG 4_4 Blowup | Pod Typology

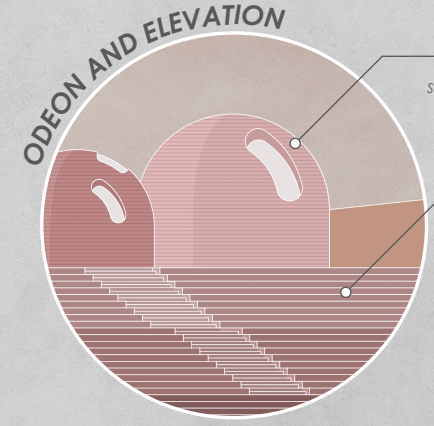
TERRACED ARCADE
Built around existing slopes such as Crater edges, Escarpments, Hills, etc.

CARVED RELIEF
Carved stone motif of journey from Earth to Mars



PLATEAU: REGOLITH BARRIER
Built up soil to contain pressure and offer radiation protection
Offers surface access / transportation with Rovers

ARCUATE STRUCTURE
Constructed from Laser-Cut heavy stone masonry



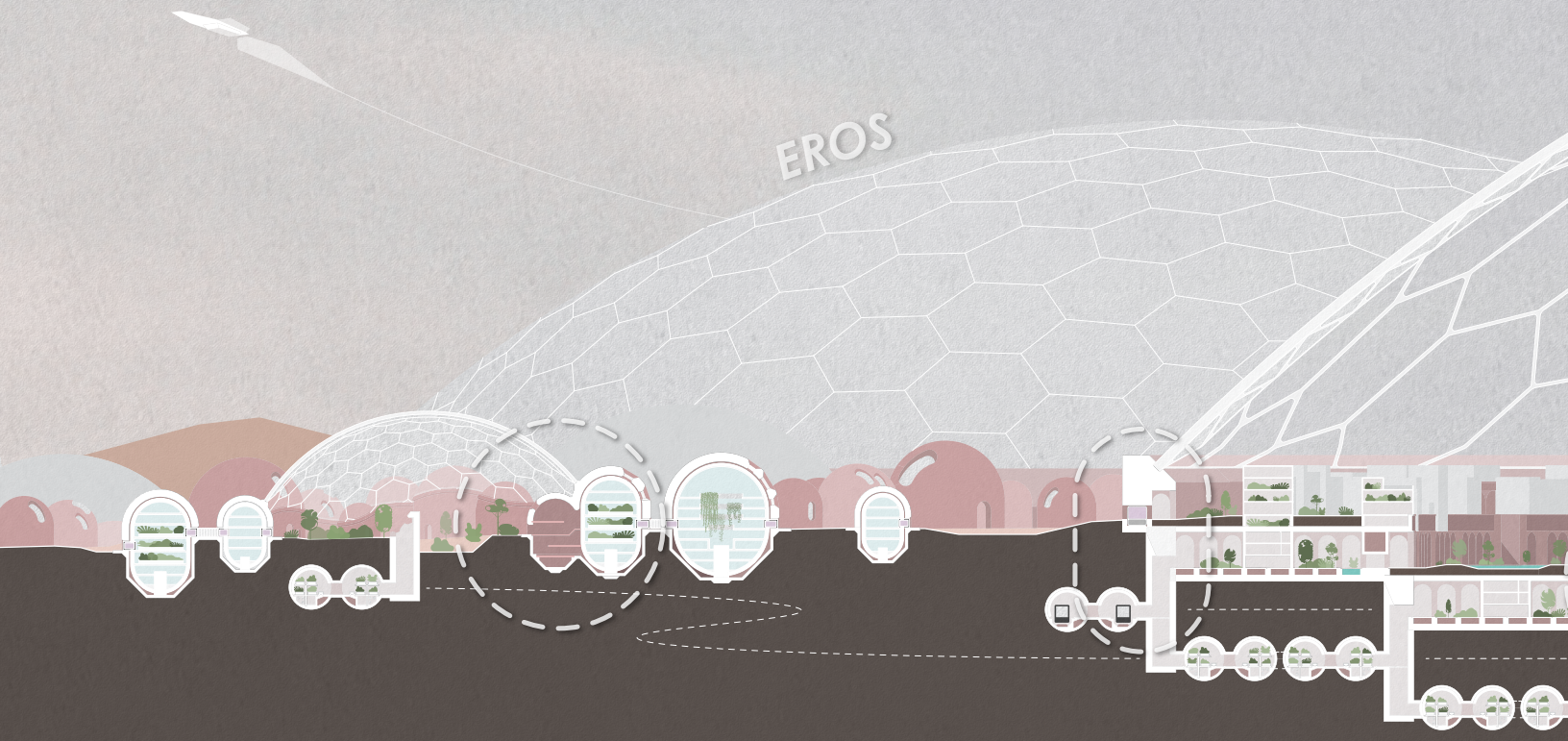
REGOLITH PODS
Autonomously 3D-Printed Regolith Concrete Pod Structures
Surrounding Crater, Organizing organically into complete rings

ODEON
Stone Laid steps at multiple scales (Human and Martian)
Cut through Arcade Structure for access at each level

DWG 4_5 Blowup | Odeon

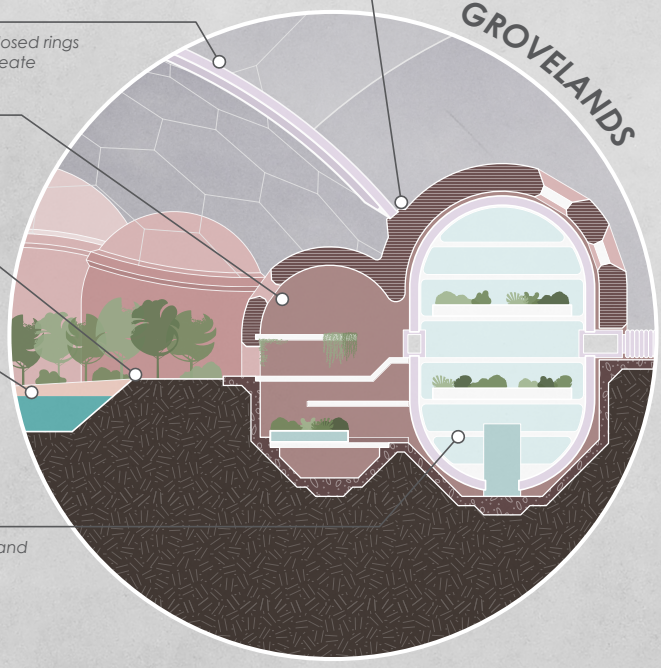
YEAR 83

Earth Year	*156*
Planet Population	*1,856,000*
City Population	*26,235*
Avg. Surface Temp.	*-21°C*



DWG 4_6 MY83 Crater Section

PSYCHE



DOME CONNECTION
Dome 'retrofitted' onto existing 3D printed pods, wraps around interior of circular aggregation

DOMED PODS
Aggregated pods organized into enclosed rings
Covered with small-scale domes to create 'interior' surface space

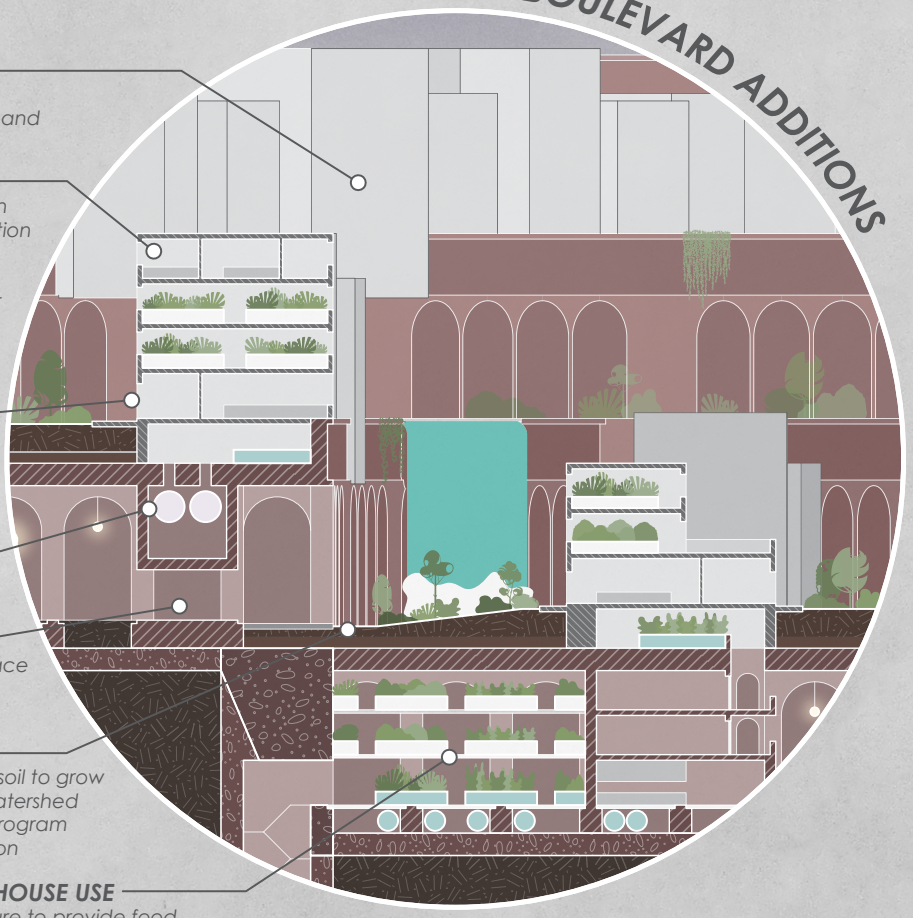
REPURPOSED DOMES
Pods within 'domed' space to have inflatables removed and infill structure take its place

GROVE
Enclosed dome spaces to be used for intensive, focused growth of plants with specific environmental requirements

SURFACE POND
Small surface ponds within Groves provide water as required

EXISTING EXTERIOR PODS
Pods at outer ring of groves maintained and repurposed for public / private living

DWG 4_7 Blowup | Grovelands



STREET ELEVATION
Combination of 4 to 8 storey fronts
Juxtaposition of Early Martian Arcades and newer Building Additions

BUILDING ADDITIONS
Lightweight Metal Alloy and Salt-Stone construction
Arcade used as Foundation and extension of function
Typically 3-4 Storeys (Limited)
Contains public and private use
Extension of Urban Greenhouses provide food for desired Public Program
Eg. Bakery, Restaurant, Brewery etc
Private use at Upper level

STREET FRONT
Public Programs offered by residing individuals

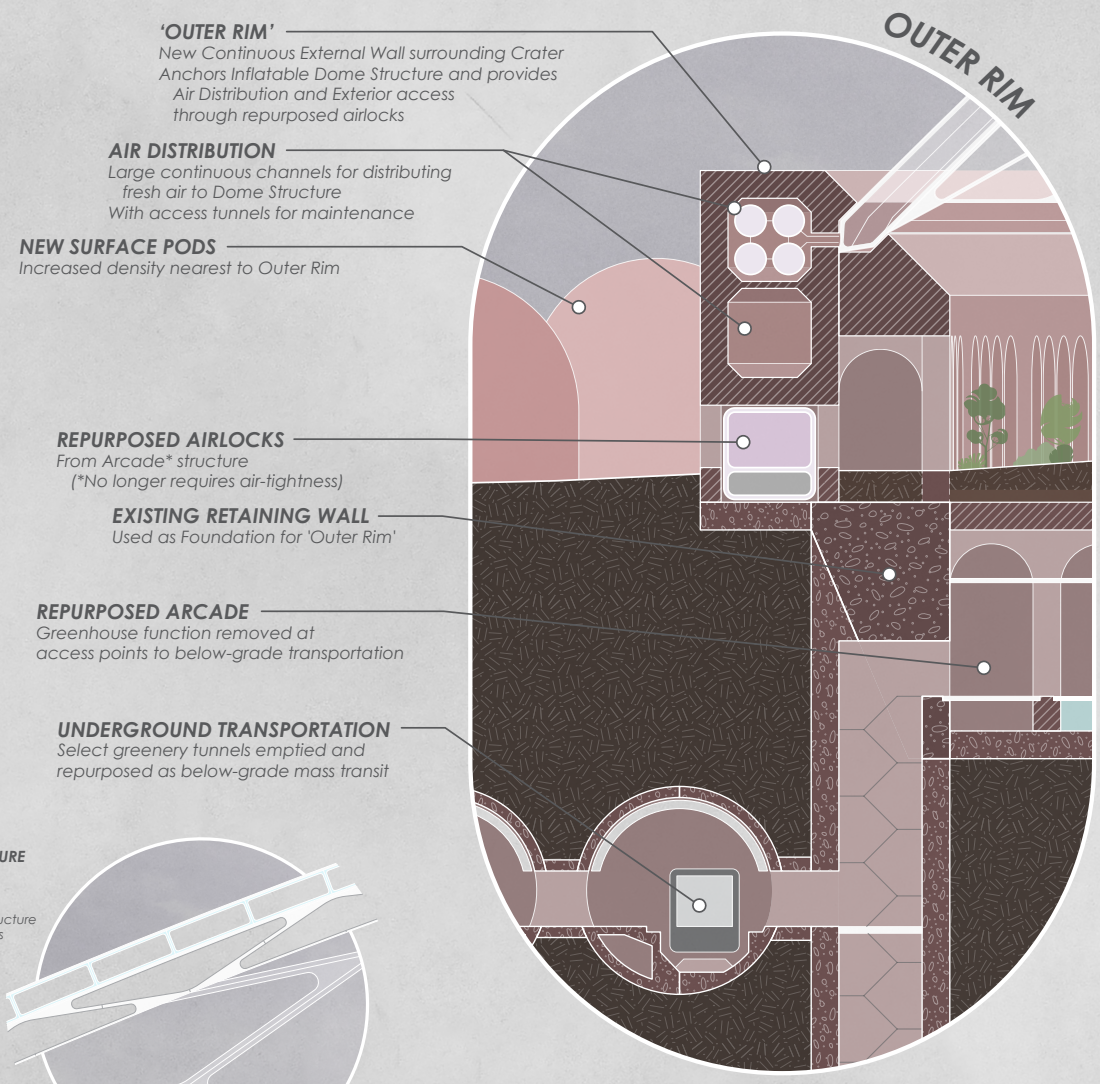
SERVICES
Access extended to Building Additions

REMOVED AIRLOCKS
Provides open access to Extended Public Space
Brings 'Streetfront' Inside and offers sheltered Public Program

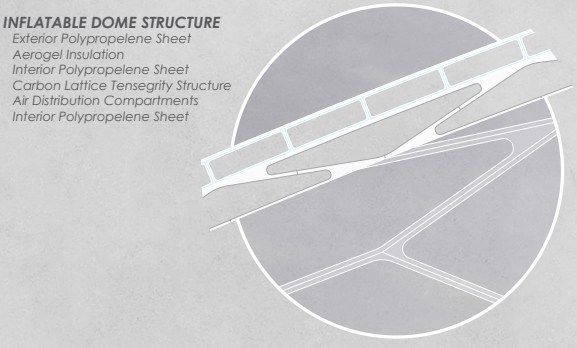
SURFACE GARDENS
'Plateau' recreated with healthy soil to grow gardens and create surface watershed
Becomes 'Streetfront' for Public Program
Designed for Pedestrian circulation

CONTINUED GREENHOUSE USE
Uses existing infrastructure to provide food for growing population

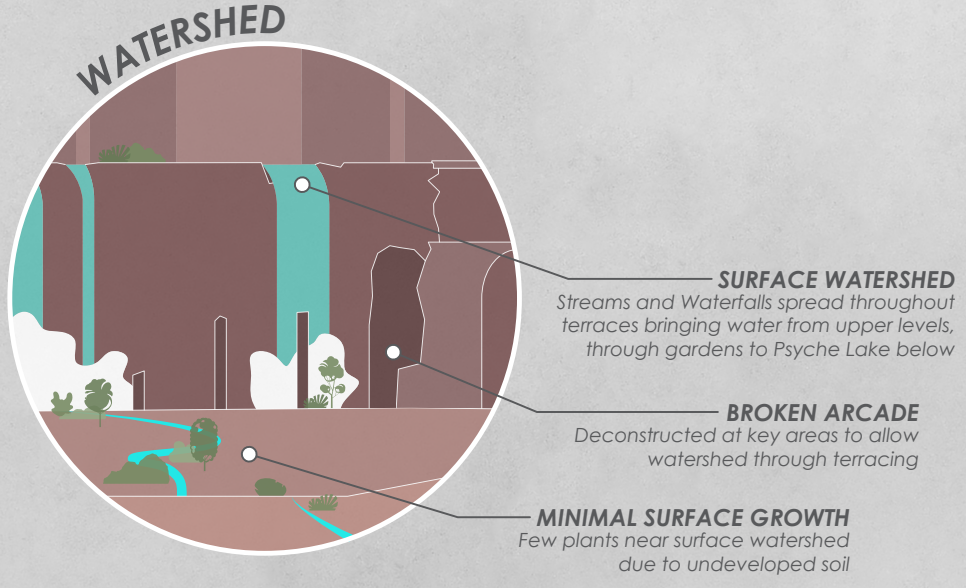
DWG 4_8 Blowup | Boulevard Additions



DWG 4_10 Blowup | Outer Rim



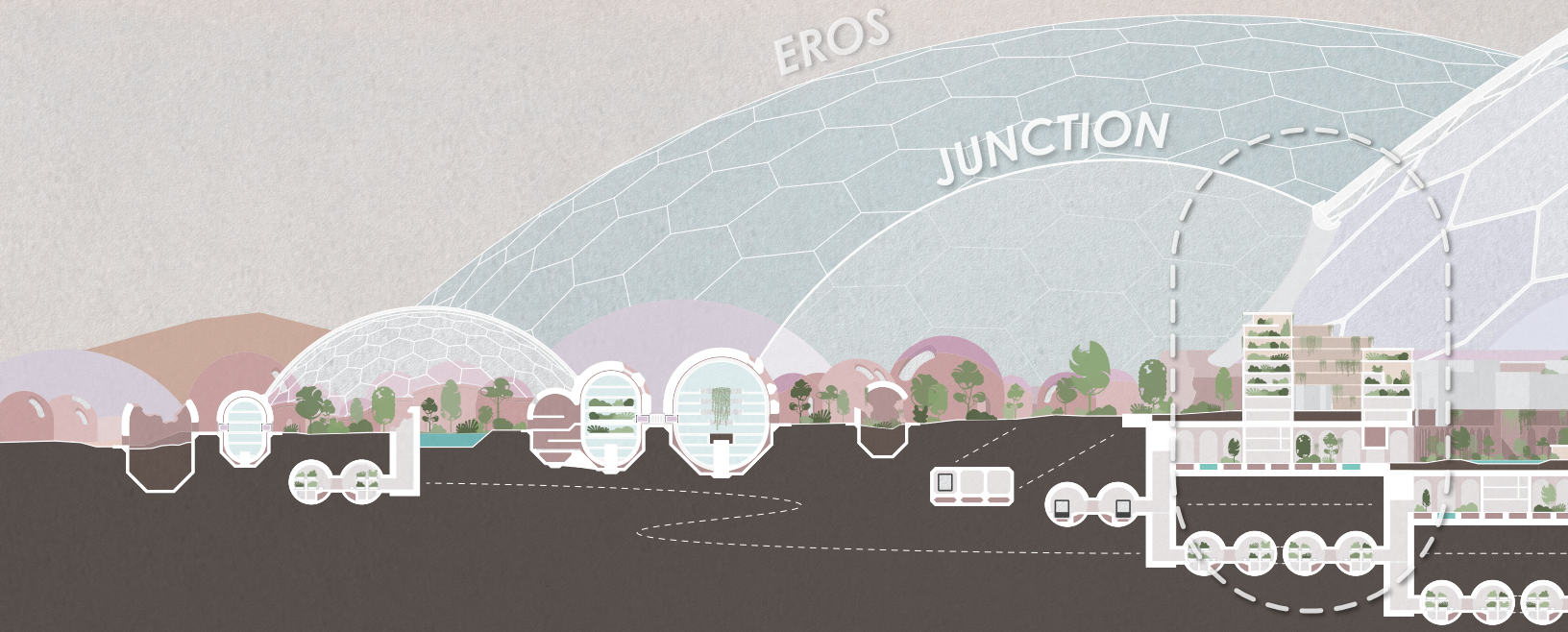
DWG 4_9 Blowup | Dome Structure



DWG 4_11 Blowup | Watershed

YEAR 216

Earth Year	*406*
Planet Population	*33.24 mil*
City Population	*204,560*
Avg. Surface Temp.	*4°C*



DWG 4_12 MY216 Crater Section

PSYCHE
GATEWAY

PARKS & FORESTS

MATURED FOREST
Mature soil offers complex nutrients for extensive biodiverse plant growth
Plants genetically altered for radiation resistance

WATERSHED
Streams outflow from terraces through parks towards Lake below
Combination of canals, streams, waterfalls etc.

PSYCHE LAKE
Complex biology of flora and fauna
Freshwater plants and fish to cycle nutrients and clean water

DWG 4_13 Blowup | Parks and Forests

TERRACED TYPOLOGY

STATIC MESH
Mesh domes now thinner, internally pressurized
Statically charged to repel dust buildup
Allows diffusion of Air out, not in

MAINTAINED DOME
Existing second generation dome,
maintained to retain radiation resistance

DOME MERGER
Mechanically sealed seam where Pod
aggregations adjoin to Outer Rim

'JUNCTION'
Large 'outdoor' spaces where Dome Mergers occur
'Outer Rim' deconstructed to allow at-grade
circulation and connection

BUILDING EXTENSION
Wood additions added to existing historical
steel structures
Densify and continually add farming program

ELEVATION
New wood extensions added to create
courtyard buildings, adding living and urban
farming space
Allows 'Street' to continue below

WATERSHED
Surface waterflow throughout streets brings
water from top terraces to Psyche Lake below

URBAN FARMS
Large-scale urban farming ensures
availability of food for all

EXISTING BUILDINGS
Second Generation steel and masonry buildings
maintained and used as base for extensions

PUBLIC PROGRAM
At-Grade public programs such as restaurants,
gyms, social hangouts etc.

PUBLIC BATHS
Outer Arcade offers public programs
Interior water storage creates public baths
for cleansing of Martian dust

FOOD STORAGE
AND DISTRIBUTION
Underground greenhouse reused for
storage / logistics of food distribution
around Craters and beyond

MASS TRANSIT
Access to short range (Crater) and
long range (City-Wide) public transportation

UNDERGROUND STATION
Inner Arcade repurposed as transportation hub
at key connection points throughout Craters

TUNNEL LIFT
Carries germinated plants from tunnels to
Arcade for further distribution

TUNNEL DISTRIBUTION
First point in bringing germinated plants from
tunnel network to surface for further growth

DWG 4_14 Blowup | Terraced Typology

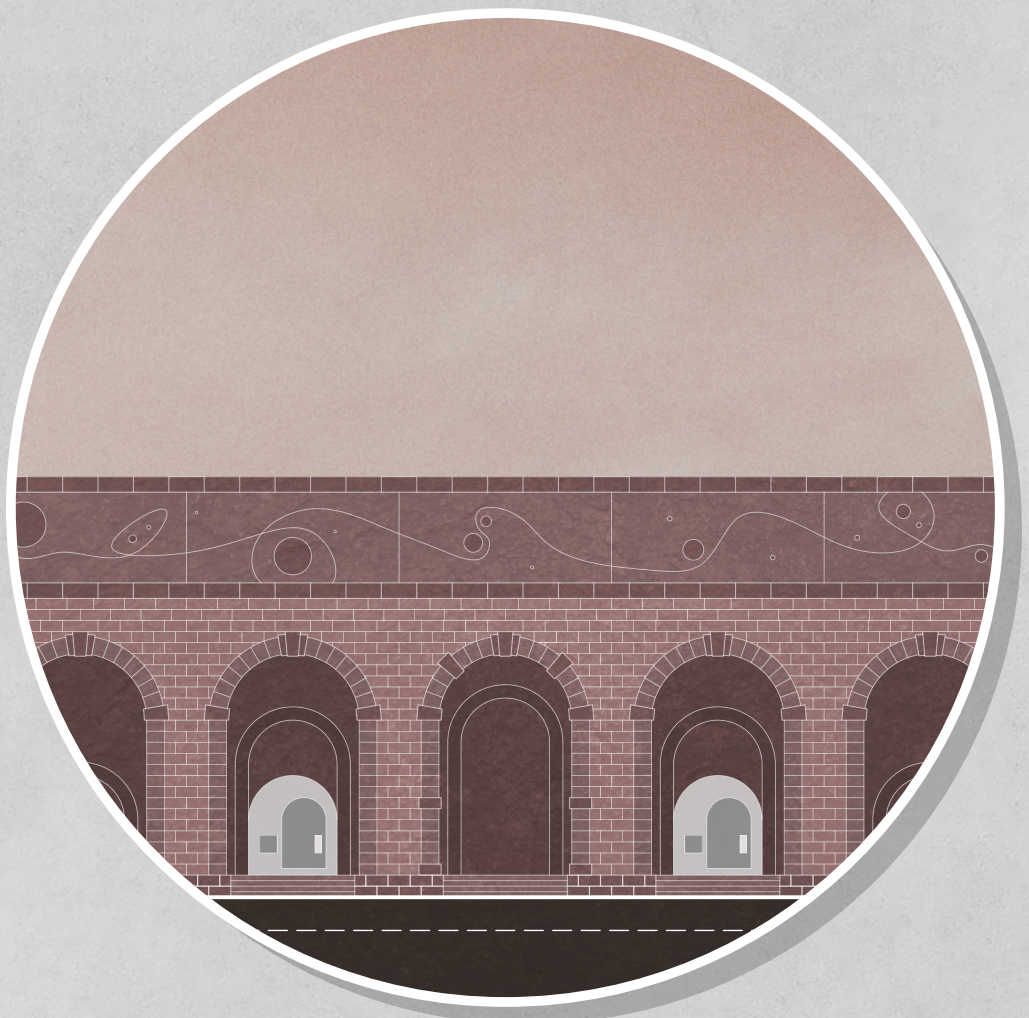
Elevations

The resulting series of elevations displays the evolution of a streetfront through three generations of construction and ecology.

The first, a heavy stone arcuate structure, nestled into the edge of the crater. Zero green surface life, or visible life at all.

The second, an addition of lighter, interspersed buildings upon the arcade foundations. Greenery planted, but relatively immature.

The third, an inclusion of natural, renewable materials continues in upwards expansion. Ecology has matured to a resilient state.



DWG 4_15 Elevation | Martian Year 18

DWG 4_16 Elevation | Martian Year 83

DWG 4_17 Elevation | Martian Year 216

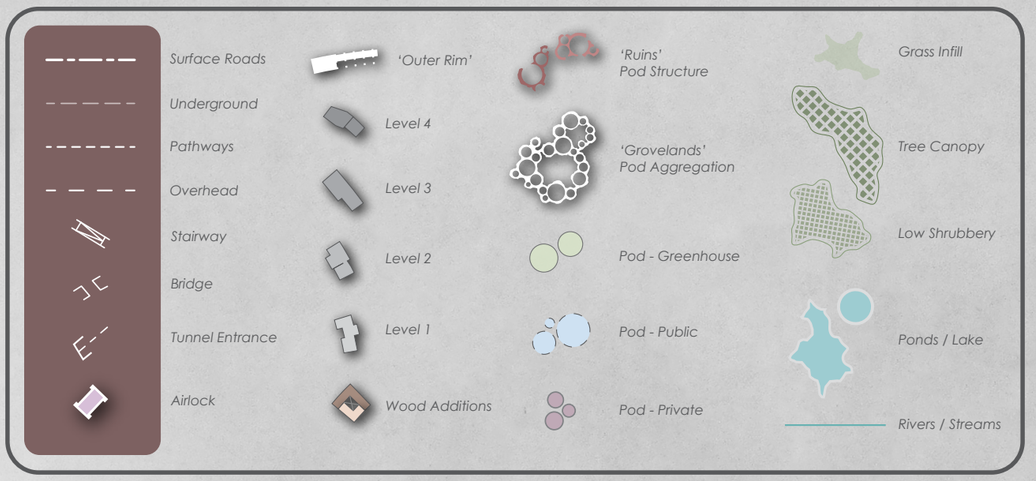
Res Publica

The resulting agricultural town displays the multi-layered development of two unique typologies, each offering a different method of organizing space and combating the elements. Organically shaped courtyards exhibit the slow abandonment and reuse of pods to reorganized into a foam-like fabric. This fabric of the Grovelands expands to merge into the Outer Rim of each crater. Within, urban blocks of 3-5 storeys are intermixed with newer wood additions and towers, mirroring the radial grid of the steadfast stone arcade below, ultimately informing the shape of streets and squares.

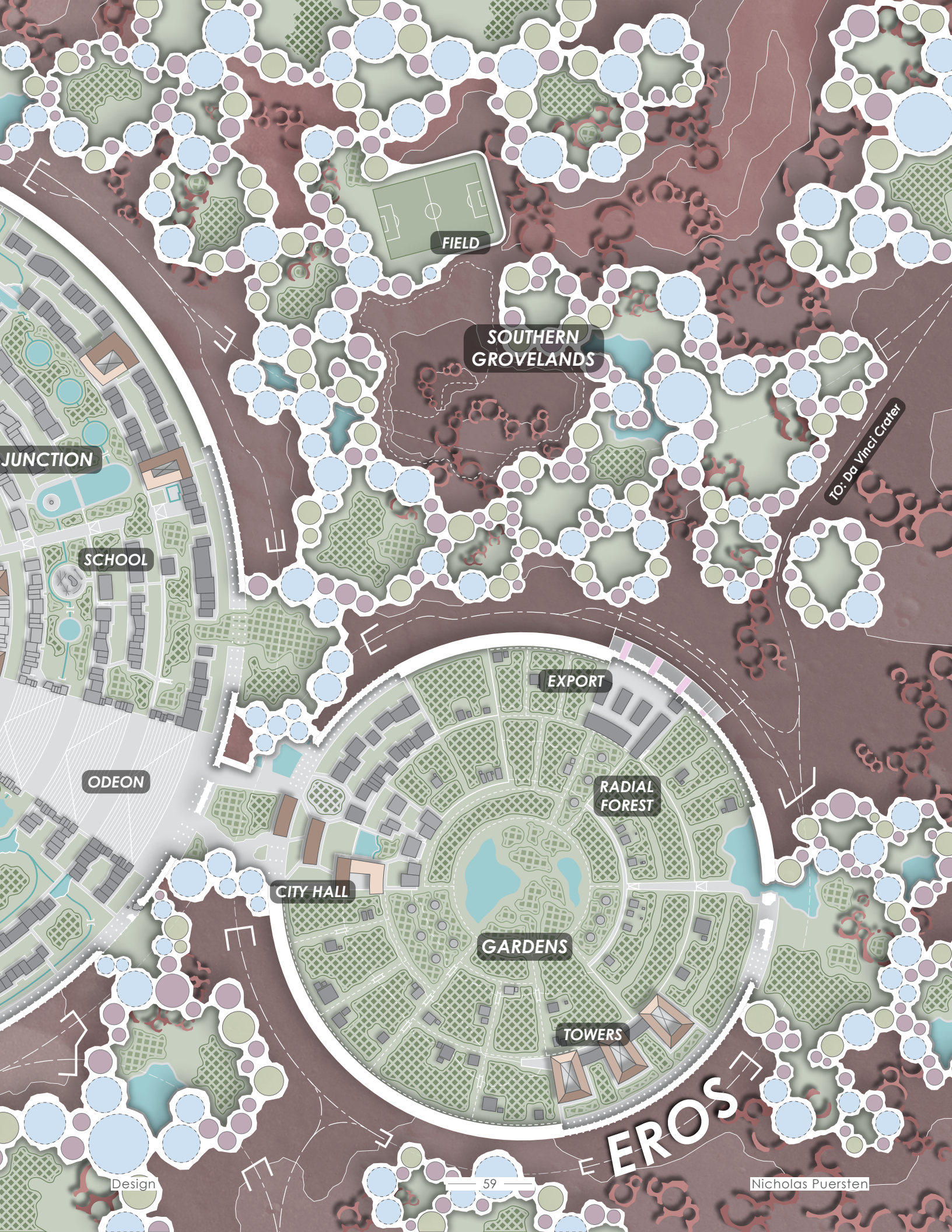
Public institutions like schools and hospitals are interspersed with distinct, recognizable landmarks such as the Odeon. Now surrounded by buildings, it becomes a centralizing public space leading directly towards Eros and its forested grounds. A landscape that is teeming with mature ecology from large parks and renewable forests to small public squares and streetways is dissected by a complex surface watershed cycling water down through the terraces and back into a central lake.

DWG 4_18 Blowup Plan | Crater

LEGEND



DWG 4_19 Plan | Psyche and Eros


FIELD
SOUTHERN GROVELANDS
JUNCTION
TO: Da Vinci Crater
SCHOOL
EXPORT
ODEON
RADIAL FOREST
CITY HALL
GARDENS
TOWERS
EROS

Tracing the slow, progressive growth, it is clear how the urban blocks of the crater, its terraces and streets, the scattered pod-foam of the Grovelands and all their intricately connected courtyards are intrinsically shaped by the pattern of radiative and atmospheric forces that first prohibited inhabitation.

In Green Mars, *Kim Stanley Robinson discusses a concept called* ***viriditas****: the organization of matter into patterns creating life as we know it. The act of terraformation is then to simply guide Mars back towards its pattern state. And, almost unintentionally (in fact with great necessity), the architecture and urban spaces we create for ourselves reflect these patterns, molding a res publica that is undeniably Martian.*

Conclusion

Results and Drawbacks

I believe this design experiment was a success, combining elements of technology and engineering, architecture and urban planning theory, planetary science, site significance, and a complex human experience and mythos. Humans are often highly predisposed to imagining the means of our own destruction, however in a world plagued by doom and despair, I wanted to envision a project that is hopeful about the direction of humanity.

Admittedly, the architectural design of this project is more or less limited, as focus was generally placed on the formation of the res publica as a whole. It does not seek to imagine something wildly different, but rather combine existing technologies and their predicted successors with sound urban planning theory. At a glance, this thesis then reflects tropes of Martian architecture such as geodesic domes and inflated pods. This is not due to an adhesion to any specific design principle, but a result of the influence of environmental factors and universal laws, potentially making these design choices inescapable (at least until successful terraformation is achieved). Beyond that simple visual association however, this projects seeks to imagine the growth of Martian public space and human life to a depth that I believe has not been explored beyond the written word.

It is important to note however that this project is only one plausible future within an infinite set of options. It draws from sound research and proven technologies, however given the significant advances in technology even within the past 20 years, it may be impossible to accurately predict where humanity might be in another 20, let alone the span of 400 or so years that I have projected. Perhaps revolutionary advancements in general artificial intelligence or nuclear fusion will radically change the trajectory of humankind; these changes alone could lead to a drastically different vision of Mars. It is also important to note that this project is not intended to be a final vision or masterplan of the Martian res publica. Even further into the future, expansion of greenery could continue, domes could become completely obsolete among a myriad of other changes, new typologies could be overlaid, interweaving into the palimpsests of previous generations.

Throughout the design process, some major assumptions were made in order to guide the direction of its growth and avoid some of the harsh realities of Mars. It assumes that no freak disasters occur like meteorite or asteroid collisions, or even massive landslides resulting from terraformation. The reality of Mars is that tragedies such as these are almost inevitable and could lead to the destruction of a city in the blink of an eye. It also makes smaller, but not inconsequential assumptions, such as the structural integrity of Martian stone after the introduction of moisture.

Unfortunately, Mars is a cold, dark, dry wasteland of stone and sand. It is exciting though to imagine a future in which these harsh realities could change.

DWG 5_1 Perspective | City Aerial View

Who will Build It?

The consideration must be made as to exactly who are the people that will construct not only this city, but the entire ecosphere of Mars.

This thesis follows quite closely the narrative of Kim Stanley Robinson's *Mars Trilogy*, and thus assumes a very similar population trajectory; due to the intense requirements for pioneering, it is likely that the first people on Mars will be diverse, experienced, and highly educated in multiple fields of research, and will likely have accepted that Mars is a one-way ticket. These people will likely not be the ones funding the project, and as such will immediately be faced with a decision upon landing: do they follow orders given by a team of people on the other side of the solar system, or do they decide to create a new agenda for themselves, reimagining society from the ground up? *Mars Trilogy* explores the latter in depth, and that trajectory is adopted throughout these design explorations.

The next test will come from whether or not people choose to, or even can return to Earth, or if they are slated to spend their remaining years on the red planet. After that, there is even the question whether population growth through natural birth is adversely affected by both the micro-gravity and levels of radiation. That being said, both of these factors will greatly affect the potential creation of a free and independent Mars.

At the current time of writing this thesis, plans of colonization and terraformation lie mainly in the hands of SpaceX, and ultimately Elon Musk. If everything goes according to his vision, the hope of a diverse, equitable group of forward-thinking individuals is dim. A harsh reality wherein a lower class of workers are sent to Mars to construct infrastructure and amenities, thus assuming all of the risk, while oligarchs such as Musk wait out the dangerous tasks to reap the benefits and ensure a controlling hand over the mission, ascending to become the Lord of Mars.

In my personal opinion, this potential future is bleak, and if Mars ever comes within humanity's reach, I would hope to see a radical reimagining of how human beings might live and work together, overcoming their differences to become stewards of life, rather than dominators of it.

Bias

Of course, I must draw attention to the shortcomings of my own perspective, that of me being a young white male, educated in a western school. This means that the design is founded mainly in North American and European theories of architecture, urban planning, culture, zeitgeist, sci-fi etc.

It is interesting to imagine how a project designed by a student in Peru, or Indonesia, or Nigeria, or China, or really any other location would be radically different to my own design. And I would argue that a plethora of perspectives from all different walks of life is necessary to fully flesh out an idea of what an equitable, diverse Mars (and future) could truly look like.

Implications and Opinions

The lessons learned from this thesis reflect a message of resiliency and longevity. To me, it draws attention to the current short-term thinking of not only the construction industry, but our entire economy.

On Mars, materials must be conserved to their absolute limits, and all methods of production must be contained within closed-loop cycles. Crafting a culture and an economy surrounding these life-sustaining requirements could begin to influence how systems of production are viewed on Earth. As well, the undertaking of a planetary-wide mission such as terraformation would undoubtedly allow us to better understand the influence we have on Earth's atmosphere. At a time when climate catastrophe looms over our future, perhaps lessons from Mars could inform how we go about healing our planet from the damage we have already inflicted.

This then begs the question: given the current state of global affairs, is it frivolous to dedicate enormous amounts of resources to a wasteland planet in the hopes of making it inhabitable, while so much suffering continues to plague a vast majority of the world's population? In my personal opinion, I believe that the potential benefits (technological, geological, cultural etc.) from human boots on another planet far outweighs both the cost and risks. The cost of terraformation both in raw material from Earth and human life seems exceedingly high for such a risky venture, but promises a level of insurance for the human species than any other: a Planet B.

It can absolutely be said that our attention and efforts would be best suited to seeking out solutions for sustaining our home planet, but who is to say that these answers are not on Mars? If no manned Mars missions ever occur, we might never know.

For now, visions of Martian utopias will remain within the realm of science fiction and architectural theses.

DWG 5_2 Perspective | Terrace View

DWG 5_3 Perspective | Streetfront Park

Back Matter

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Designing for Mars

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