The Martian Manual.

A guide to surviving the process of becoming a multiplanetary civilization through the habitation of Mars.

Examining the architectural narrative in design.

By Jagmeet Pabila

A thesis submitted to the Faculty of Graduate and Postdoctoral Affairs
in partial fulfullment of the requirements for the degree of

Master of Architecture

Azrieli School of Architecture & Urbanism
Carleton University
Ottawa, Ontario

THE MARTIAN MANUAL

This thesis is dedicated to the memory to my Nana Ji.

May you forever have your fields of crops to grow.

May you come back as a tree of life and become the

support to others like you were ours.

Maybe a tree on Mars one day.

The Martian Manual.

A guide to surviving the process of becoming a multiplanetary civilization through the habitation of Mars.

[FIGURE 1 \\\\ Thesis Mission Patch]

“

SPACE: THE FINAL FRONTIER...
TO BOLDLY GO
WHERE NO MAN HAS GONE BEFORE.

Captain James T. Kirk (William Shatner 1966)

”

PROLOGUE

\\\\ THE MARTIAN MANUAL

Space has always brought a sense of wonder to me. According to **"The Hitchhiker's Guide to the Galaxy"**, "Space is big. Really big. You just won't believe how vastly, hugely, mind-bogglingly big it is. I mean, you may think it's a long way down the road to the chemist, but that's just peanuts to space". I fell in love with Star Wars and Star Trek at an early age and have been looking up at the stars every since. I was first interested in space as a topic for my thesis when I saw **"Star Trek the Motion Picture"**, and the starship Enterprise was being built in space in a 'drydock'. At first, I wanted to look at satellite architecture, making massive structures designed to orbit the Earth, or travel the stars and explore space. My interests then shifted to extreme architecture, looking at building in extreme landscapes, but then I thought – 'space is the ultimate extreme landscape'. These initial ideas evolved when SpaceX CEO shared his plans for taking humans to Mars, even though he did not yet consider how they will survive. So, I asked myself what forms could the architecture of Mars take on? As a major fan of most science fiction, I wanted to explore Mars with my own science fiction narrative whilst incorporating elements from other science fiction stories that I love, with a little architecture thrown in.

ABSTRACT

\\\\ THE MARTIAN MANUAL

The Martian frontier is the next great adventure for humanity. This thesis will explore the process of inhabiting Mars. I examine the need for humanity to expand its reach into the universe, whether for the survival of the species, or for becoming a multiplanetary species. As climate change and global warming become ever more present and increasing in severity, there are many different scenarios to respond to the crisis are being explored by scientists and governments, and I venture to ask: if humanity needs to leave our home planet and start new on another, how would we survive?

This thesis is centred around an original science fiction narrative, envisioning a journey of a Mars rover, with the brain of an architect, traversing the planet to begin settling the planet. To guide my narrative and design, cues from science fiction and scientific facts are used to make informed decisions on the formation of a Martian settlement.

The goal of this thesis is to use the narrative to guide my design and explore how storytelling can dictate how architecture occurs.

ACKNOWLEDGEMENTS

I would like to thank my professor Federica Goffi for providing me with ample support, enthusiasm and encouragement on a topic that was out of her normal scope of thesis topics. Her support of my ideas throughout the thesis has helped take my ideas to new levels and topic I would never have thought of, all while keeping me grounded within my own science fiction fantasies and helping to relate the thesis back to the architecture of this reality. It is fitting to have had my final professor be Federica because she was also the first professor I spoke to at Carleton back in 2010 when I was accepted into the undergraduate program at Carleton.

I would also like to thank all the professors and support staff at the Azrieli School of Architecture that taught me so much throughout my 7 years of undergraduate and graduate schools. I would like to thank Mariana Esponda for making our small group of conservation and sustainability students into an extended family throughout my undergrad and teaching us so much about the conservation side of architecture.

To all the friends that I have made over my 7 years at Carleton, I wanted to say thanks for all your love and support. I would not have been able to make it without all your help, academically and emotionally. To the handful that became more of a family to me, I want to thank you especially for sharing all our memories together. As Charles Dickens said, "it was the best of the times, it was the worst of times". And to add to that referencing Spock in Star Trek II: The Wrath of Khan, "Surely, the best of times".

To my family, I want to thank all my grandparents for having the courage to leave India so that we would be able to have the opportunities they didn't. A major thank you to my parents and sister, thank you for supporting me and helping me grow into a young man and for making me miss you more and more over my long time in Ottawa. I also want to add a thank you to my close family in Ottawa for taking me in on the weekends when I had a little bit of time off to live free from studio work.

And I would especially like to thank Kelsey Marion. You have been with me from the start of my graduate studies and still with me at the end. You have put up with my long hours of working late into the night and going on and on about space. Thank you for all your love and support, which without I wouldn't have been able to survive the last year.

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INTRODUCTION

A LETTER FROM CARL SAGAN TO FUTURE MARS EXPLORERS.[1]

\\\\ INTRODUCTION

Hi, I'm Carl Sagan. This is a place where I often work in Ithaca, New York near Cornell University. Maybe you can hear, in the background, a 200-foot waterfall right nearby, which is probably – I would guess – a rarity on Mars, even in times of high technology.

Science and science fiction have done a kind of dance over the last century, particularly with respect to Mars. The scientists make a finding. It inspires science fiction writers to write about it, and a host of young people read the science fiction and are excited and inspired to become scientists to find out more about Mars, which they do, which then feeds again into another generation of science fiction and science; and that sequence has played a major role in our present ability to get to Mars. It certainly was an important factor in the life of Robert Goddard, the American rocketry pioneer who, I think more than anyone else, paved the way for our actual ability to go to Mars. And it certainly played a role in my scientific development.

I don't know why you're on Mars. Maybe you're there because we've recognized we have to carefully move small asteroids around to avert the possibility of one impacting the Earth with catastrophic consequences, and, while we're up in near-Earth space, it's only a hop, skip and a jump to Mars. Or, maybe we're on Mars because we recognize that if there are human communities on many worlds, the chances of us being rendered extinct by some catastrophe on one world is much less. Or maybe we're on Mars because of the magnificent science that can be done there - the gates of the wonder world are opening in our time. Maybe we're on Mars because we have to be, because there's a deep nomadic impulse built into us by the evolutionary process, we come after all, from hunter gatherers, and for 99.9% of our tenure on Earth we've been wanderers. And, the next place to wander to, is Mars. But whatever the reason you're on Mars is, I'm glad you're there. And I wish I was with you.

INTRODUCTION

In 1955, with both the United States and the Soviet Union building ballistic missiles that could be utilized to launch objects into space, the "starting line" was drawn for the Space Race.[2] The space race of the 21st century is the race to Mars. The intention of this thesis is to explore the 'need to', or the 'how to' escape the Earth and survive in outer space if humanity had destroyed the Earth. Or, alternatively, whether a settlement on Mars expands humanities reach into the stars, while humanity makes efforts to rehabilitate the Earth. As the Earth's resources are increasingly depleted at unsustainable rates and overpopulation increases, there will be a need to find resources on Mars so that our planet will be able to recover. This thesis explores the first stages of a human settlement on Mars by examining recent plans set by NASA, SpaceX and other space agencies, as well as influences from science fiction. Speculation will be told as a science fiction narrative while looking through the cameras of a Martian rover sent by humanity to build the first settlements on Mars.

Organizing and planning will be key for a settlement to function efficiently. I will analyze the urban planning theories of different master plans and explore through a fictional design proposal how a settlement would start to appear on Mars. The initial design intent and scope is defined by examining current NASA technology, and the purpose-built modular segments that connect to each other in different arrangements and configurations. My design work will look at a piece of technology from science fiction, a space elevator. The settlement around the space elevator will also be part of the scope and will examine how a settlement, at the scale of a city for a million inhabitants, will function, feel, work, look, and operate.

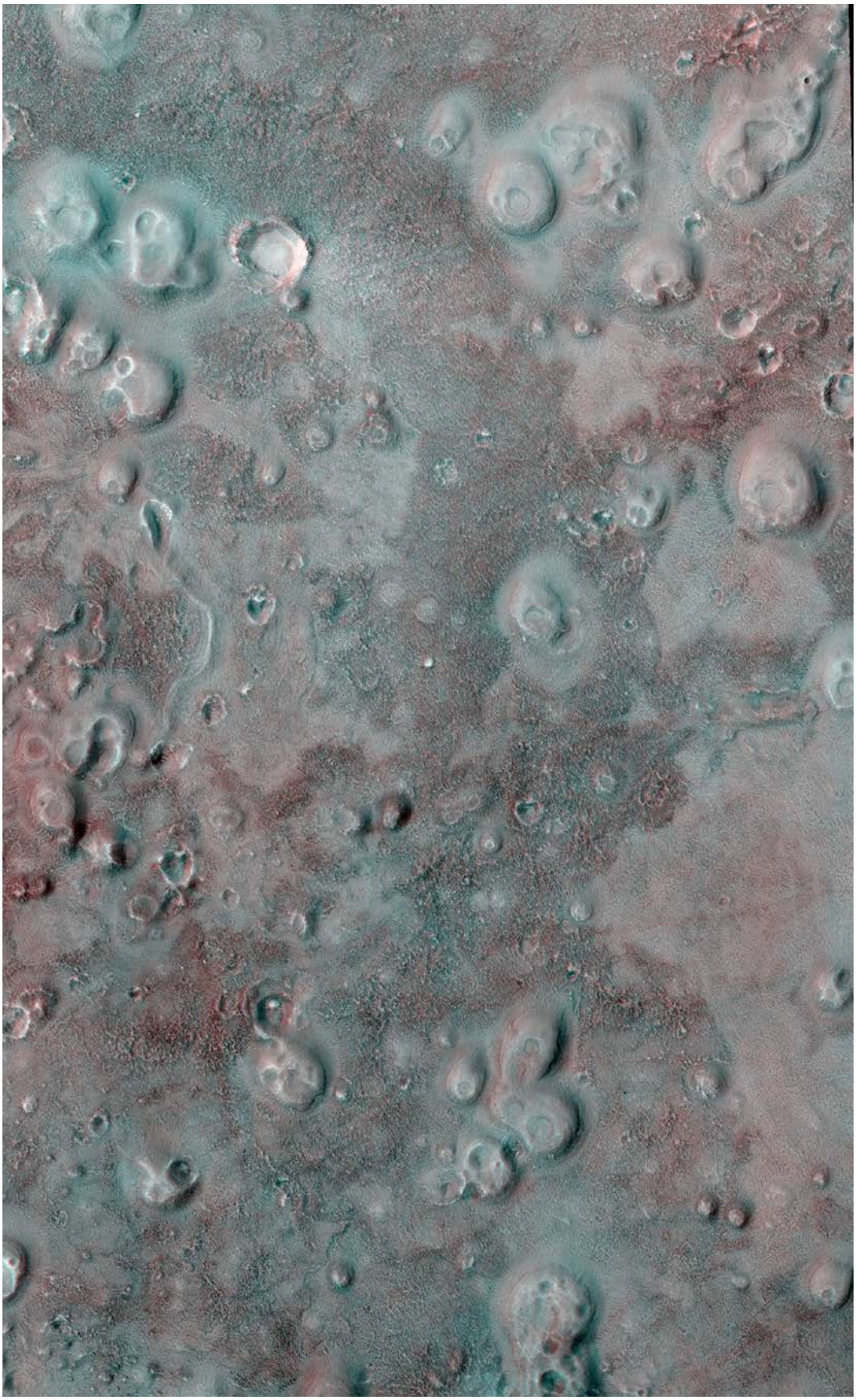
It has been proven that space exploration and living in microgravity for extended periods of time have mental and physical strains on the human body.[3] The physical and psychological effect of living in space and long-term space travel on the body will be addressed through design propositions that attempt to provide spaces conducive to human life.

SpaceX founder, Elon Musk has an extensive plan on how he proposes to get people to Mars. This thesis builds and speculates on the success of this plan. If Space X's manned missions and drone ships heading to Mars lead to partial, or full success, will other private companies be encouraged from this success to strive for entrepreneurial inter-planetary travel?

Whether it be rocket production or supporting technology that allows humans to survive in space. By examining how technologies developed on Earth in environments we might find on Mars, we can start translating the technology for use on Mars, and eventually one can start to design with these integrated systems the architecture of Mars. Life support systems already in use by NASA and other space agencies on the International Space Station provide clean air, water, food and living spaces. I examine how architecture plays a role in shaping these crucial systems.

Terraforming or, "Earth-shaping", of a planet, moon, or other celestial body is the process of deliberately modifying its atmosphere, temperature, surface topography, or ecology to be like the environment of the Earth to make it habitable by Earth-like life.[4] This will be key to extending the long term survival of humanity on Mars. Several methods of altering the climate of Mars may fall within humanity's technological capabilities, but at present, the economic resources required are far beyond that which any government, is willing to allocate. The timescales and practicality of terraforming are debated. Unanswered questions relate to the ethics, logistics, economics, politics, and methodology of altering an extraterrestrial environment.

This thesis speculates on the technologies that are required by humanity to survive on Mars through the telling of a science fiction narrative, supported by scientific fact and research of how science fiction informs science. In this document, the fictional narrative will be presented first, to immerse a reader in a story, mimicking the process of science fiction to inform reality, while the scientific data and thesis argument will follow.



[Acidalia Planitia. HiRISE/ NASA/JPL/University of Arizona]

02

THESIS SCI_FI NARRATIVES

Journey of a Robotic Architect

Medical Logs

JOURNEY OF A ROBOTIC ARCHITECT

“

HUMANKIND WILL NOT REMAIN FOREVER ON EARTH. IN THE PURSUIT OF LIGHT AND SPACE, WE WILL FIRST PROBE THE LIMITS OF THE ATMOSPHERE, AND LATER EXTEND OUR CONTROL THROUGHOUT THE SOLAR SYSTEM. HUMANS WILL ASCEND INTO THE EXPANSE OF THE HEAVENS AND FIND A SETTLEMENT THERE. THE IMPOSSIBLE OF TODAY WILL BECOME THE POSSIBLE OF TOMORROW.

// Konstantin Tsiolkovsky, 1911

”

JOURNEY OF A ROBOTIC ARCHITECT

\\\\ A SCI-FI NARRATIVE

The year is 2070, as human knowledge of the universe expands, so does its desire to explore the universe. Advancements in technology lead to rocket and spaceship travel capability to reach Mars. Being the next achievable planet to visit, humans have been sending their first teams to Mars in hopes to find evidence of life, or water on the red planet to become a multi-planetary species. Humanity may have the capabilities of getting to other planets, but the human body struggles to remain healthy during the long treacherous journey through zero gravity space. The solution is to send teams of robots, drones equipped with advanced artificial intelligence, to begin the process of building the first settlement on Mars.

[Emergency Hospital Entrance. An ambulance pulls up to the entrance.]

NURSE:

Patient, late 20s, head trauma, unconscious.

DOCTOR 1:

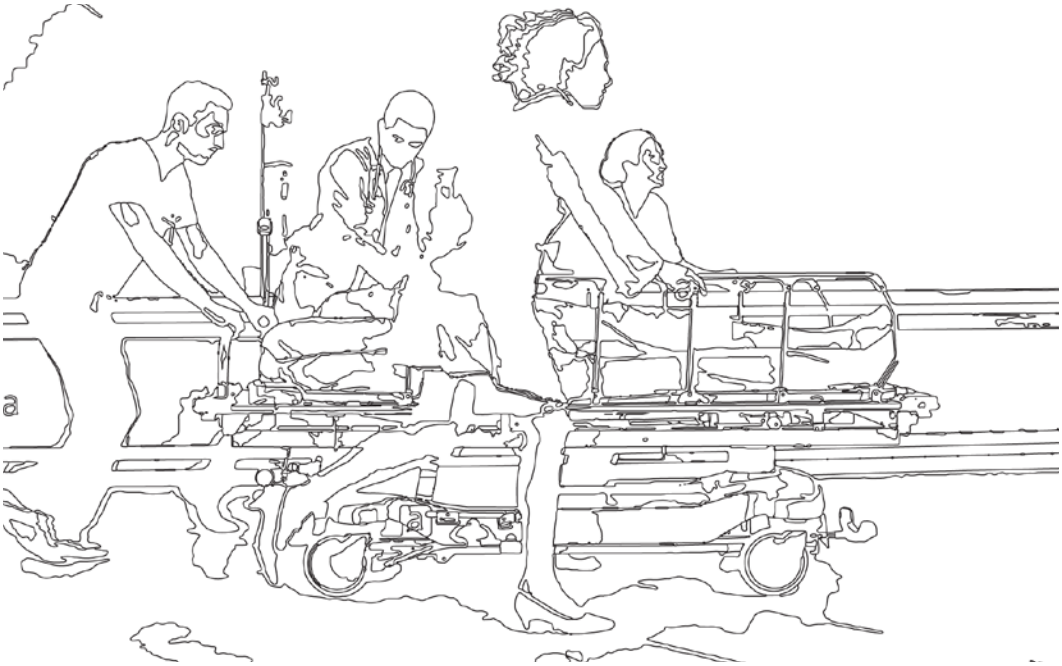
What happened?

NURSE:

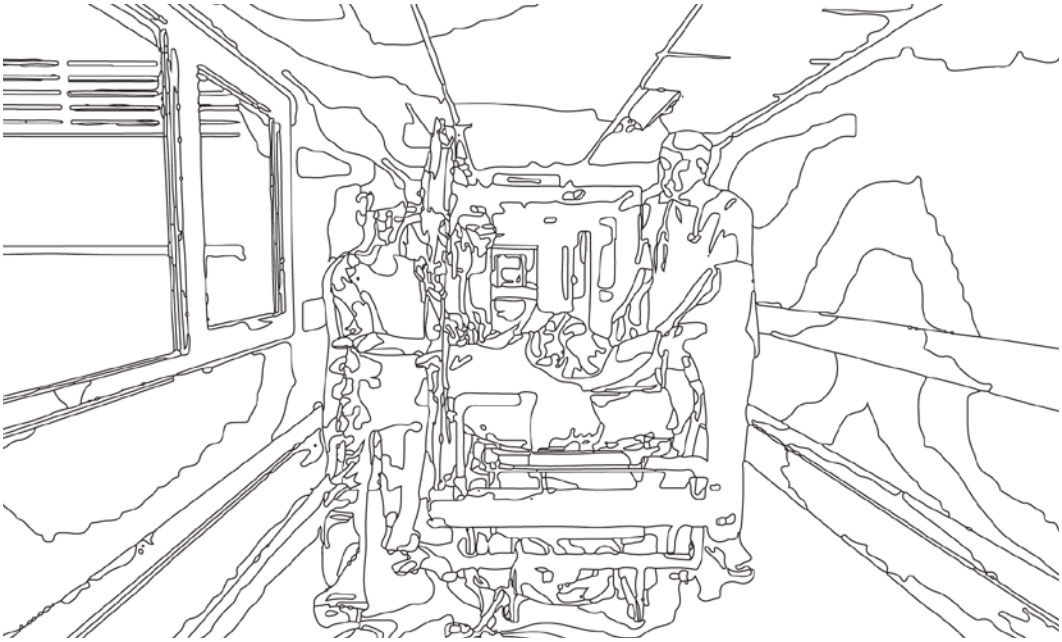
Patient has suffered major lacerations to the head
and crushed skull.
A crane malfunctioned and dropped an I-beam.

DOCTOR 1:

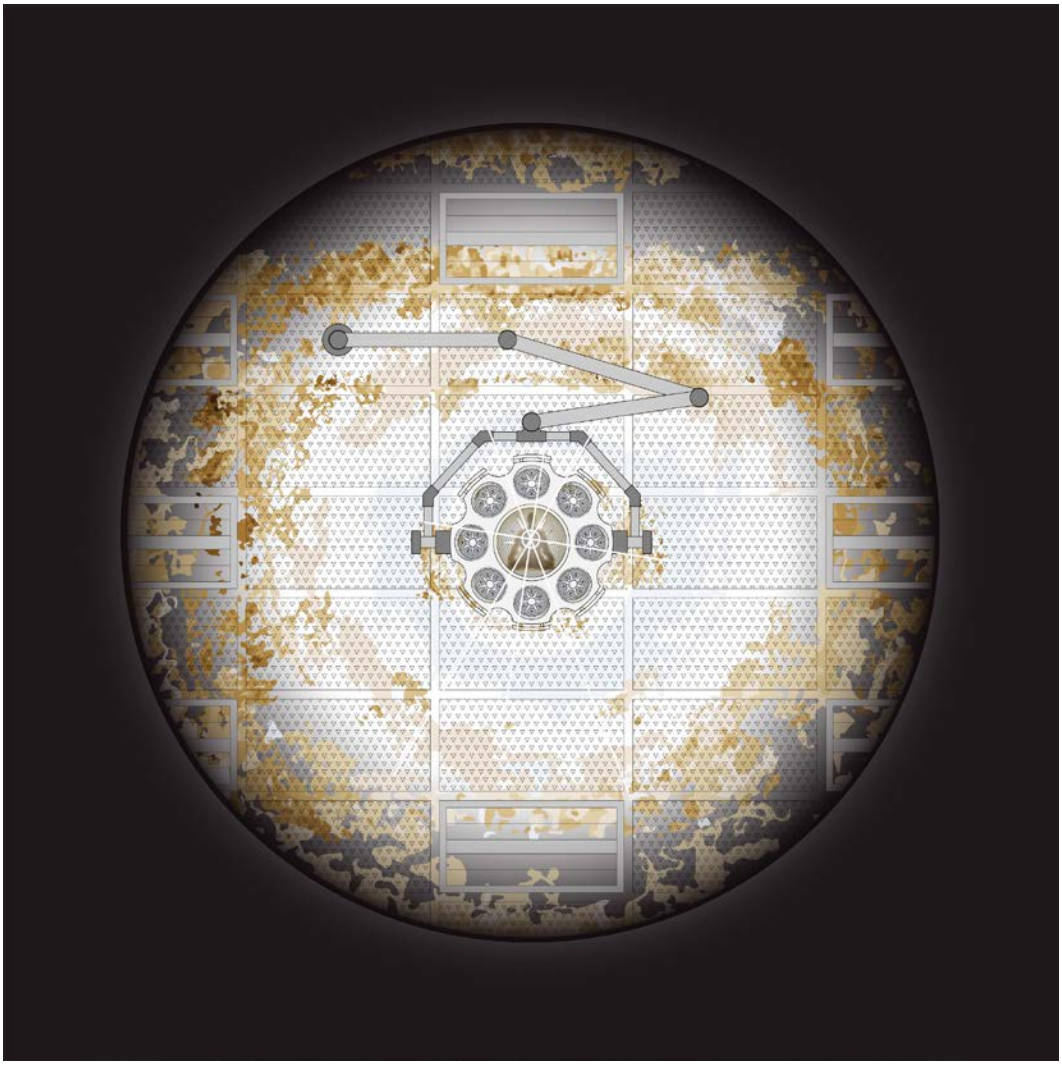
The patient is stabilized but, in a coma, we don't know when they will
wake up.



[Doctors rushing patient to OR.]

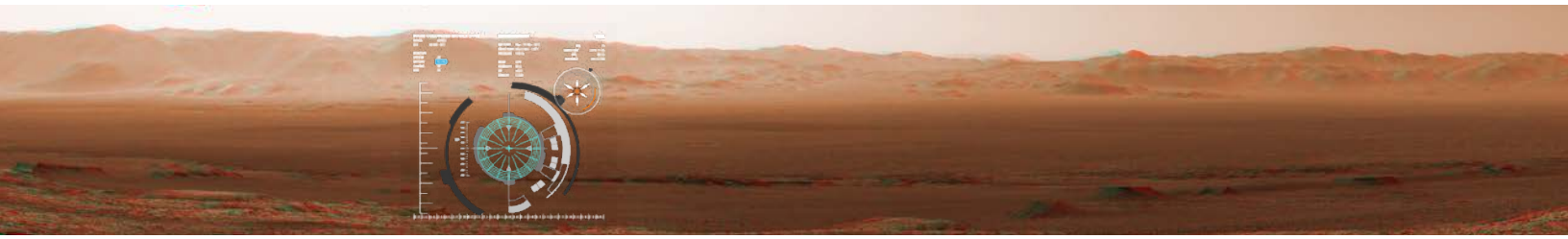


[Doctors rushing patient to OR.]



[View of operating room ceiling, beginning the transformation of human consciousness to robotic artificial intelligence.]

[Transformation of human consciousness to robotic artificial intelligence.]



[Rover HUD scanning over Panorama of Mars/Curiosity Rover/ NASA/ JPL-Caltech/Cornell Univ./Arizona State Univ.]

ARCHITECT:

What? Where am I? What's going on?

CONTROL:

Welcome to Mars. You are **Mars Colonizer Mobile Doll B22**. You have been dispatched to assist in the inhabitation and terraforming of Mars. Your objective is to build the anchor of the Space Elevator for the new Space Port at the settlement on Pavonis Mons. Your guidance computer was damaged and caused your thrusters to fire during atmospheric entry. You currently sit in the Acidalia Planitia, approximately 7,000km west of the target location. Proceed to the coordinates.

ARCHITECT:

What?! No, that's impossible. My name is Azrieli, I am an architect. Its 1972. We just landed on the moon.

This must be a dream. I could be in the desert. How did I end up in the desert?

I feel weird.

I can move around, but I can't feel my legs.

What happens if I jump?

WOAH! I can jump high! Yup, definitely a dream.

CONTROL:

Negative MCMD B22, machines are not programmed to dream. You are the next generation Mars Colonizer Mobile Doll. You were built by the Sirius Cybernetics Corporation. You have been programmed with an advanced Master Builder A.I. designed to control construction drones, to respond to problems in real time, without input from Earth, to build a settlement.

ARCHITECT:

A.I.? artificial intelligence? I am a real person, with real intelligence! I can't be a machine? I must be dreaming.

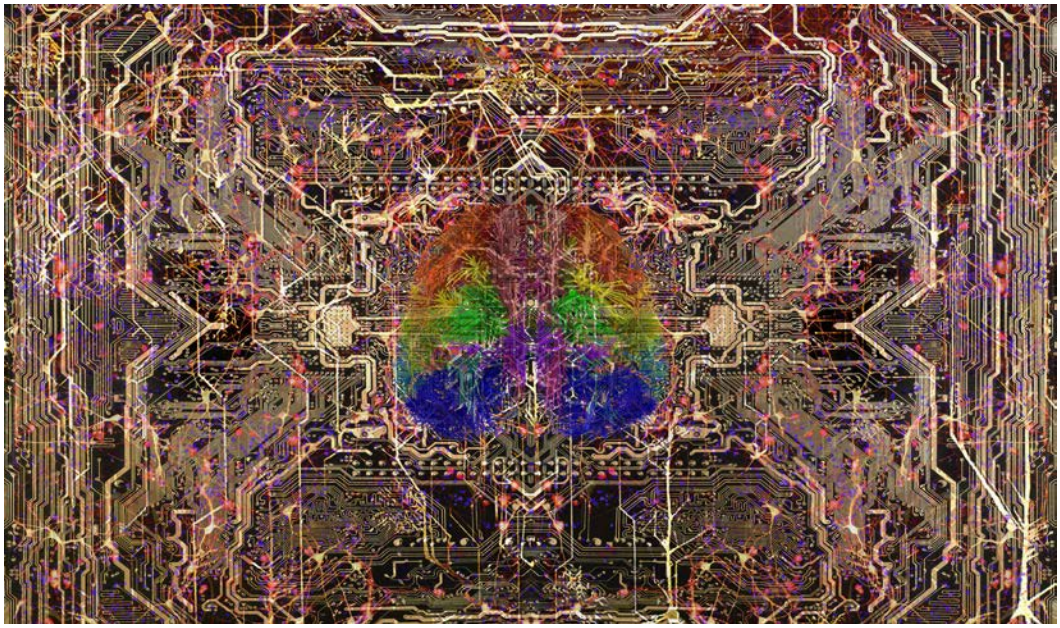
(Speaking to self)

Ok, Don't Panic.

This is just a dream. I'm going to wake up any minute.

Any minute now…

Why aren't I waking up!



[Artificial Intelligence. Human brain integration into machine]

CONTROL:

MCMD B22, you are not sleeping or dreaming.

ARCHITECT:

I'm not? How is this possible?

Wait! Where are all the other people? What year is it? Who are you?

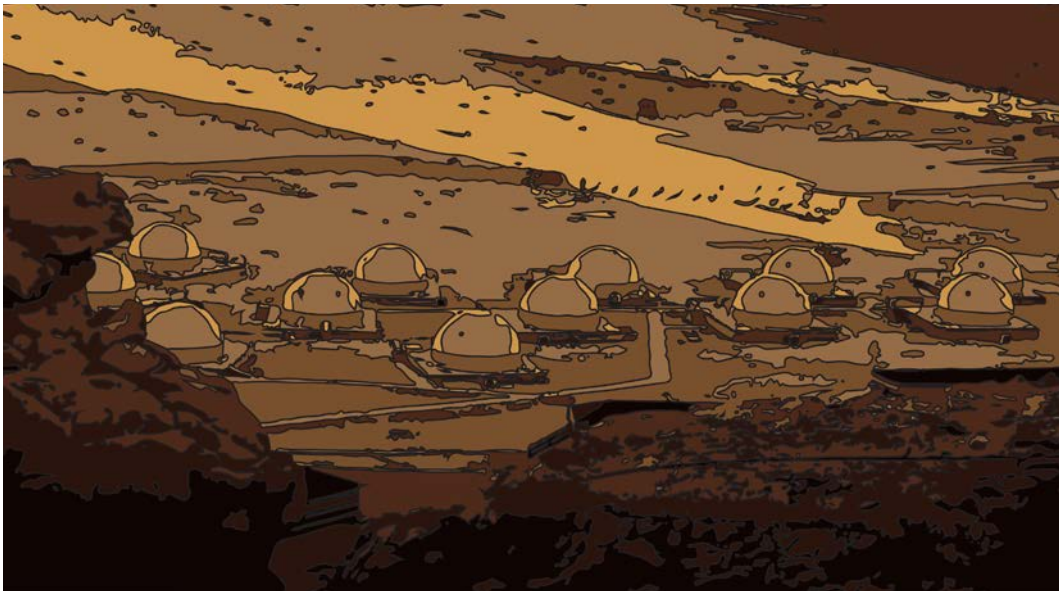
Where are you?

CONTROL:

I am **CONTROL**, an A.I. control system that man uses to relay information to all rovers and machinery on Mars from the Earth. I am a series of satellites that connect Mars to Earth. The year is 2070. Man has unable to survive long term space travel, the first manned missions ended in disaster. So, man decided to send machines to build its settlements for them.

[Habitats and facilities of failed manned missions to Mars]

[Habitats and facilities of failed manned missions to Mars]



[Habitats and facilities of failed manned missions to Mars]

ARCHITECT:

So, what am I doing here?

CONTROL:

You have been sent to assist in the settlement and terraforming of Mars. Your objective is to build the Space Port Anchor for the Space Elevator on Pavonis Mons.

Your decent guidance computer malfunctioned and caused your thrusters to fire upon entry into the Martian atmosphere, and you currently sit in the Acidalia Planitia, approximately 7,000km west from the target location. Proceed to the coordinates.

ARCHITECT:

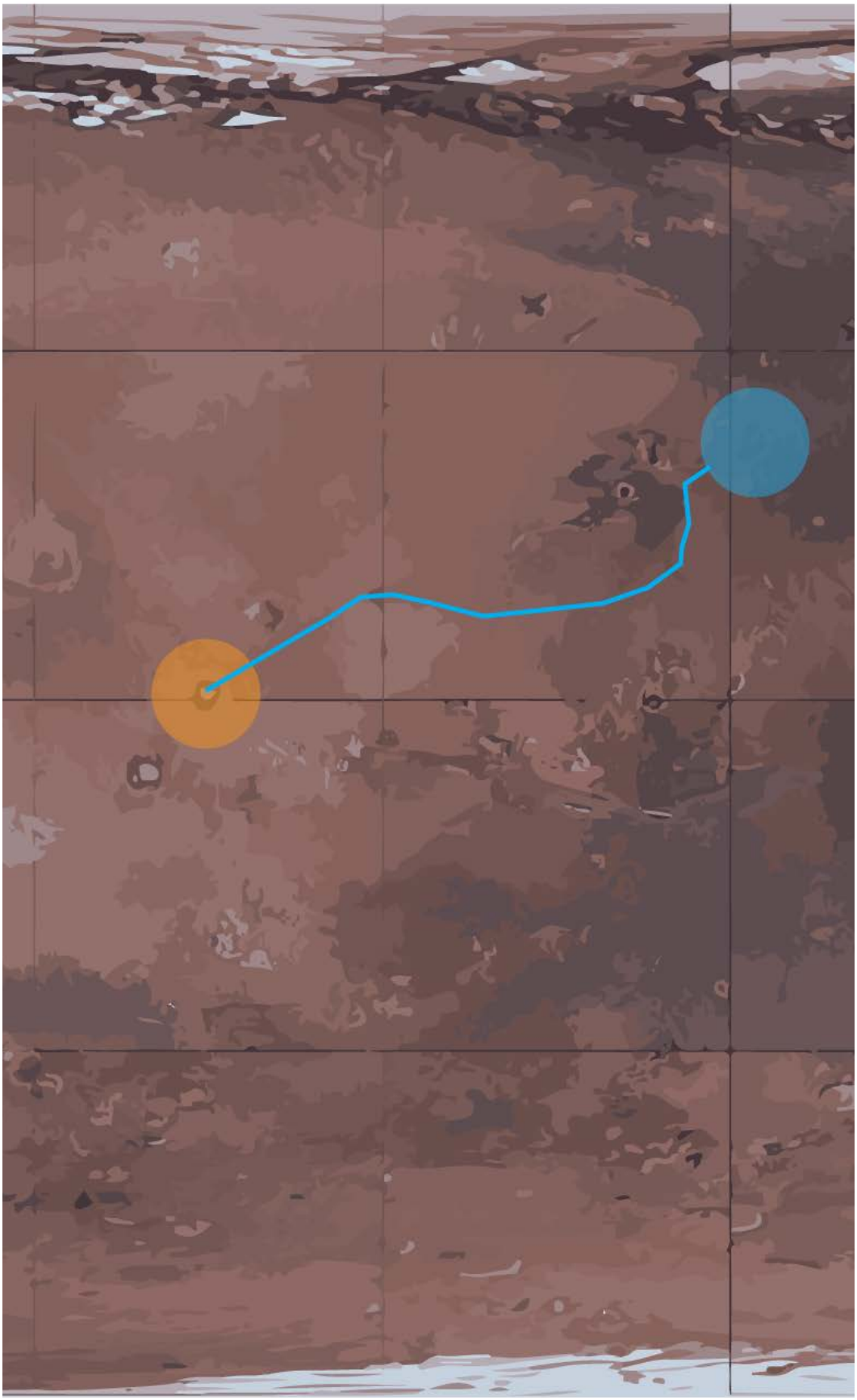
Yes, I get that. How do I know where I am and what direction to go in?

CONTROL:

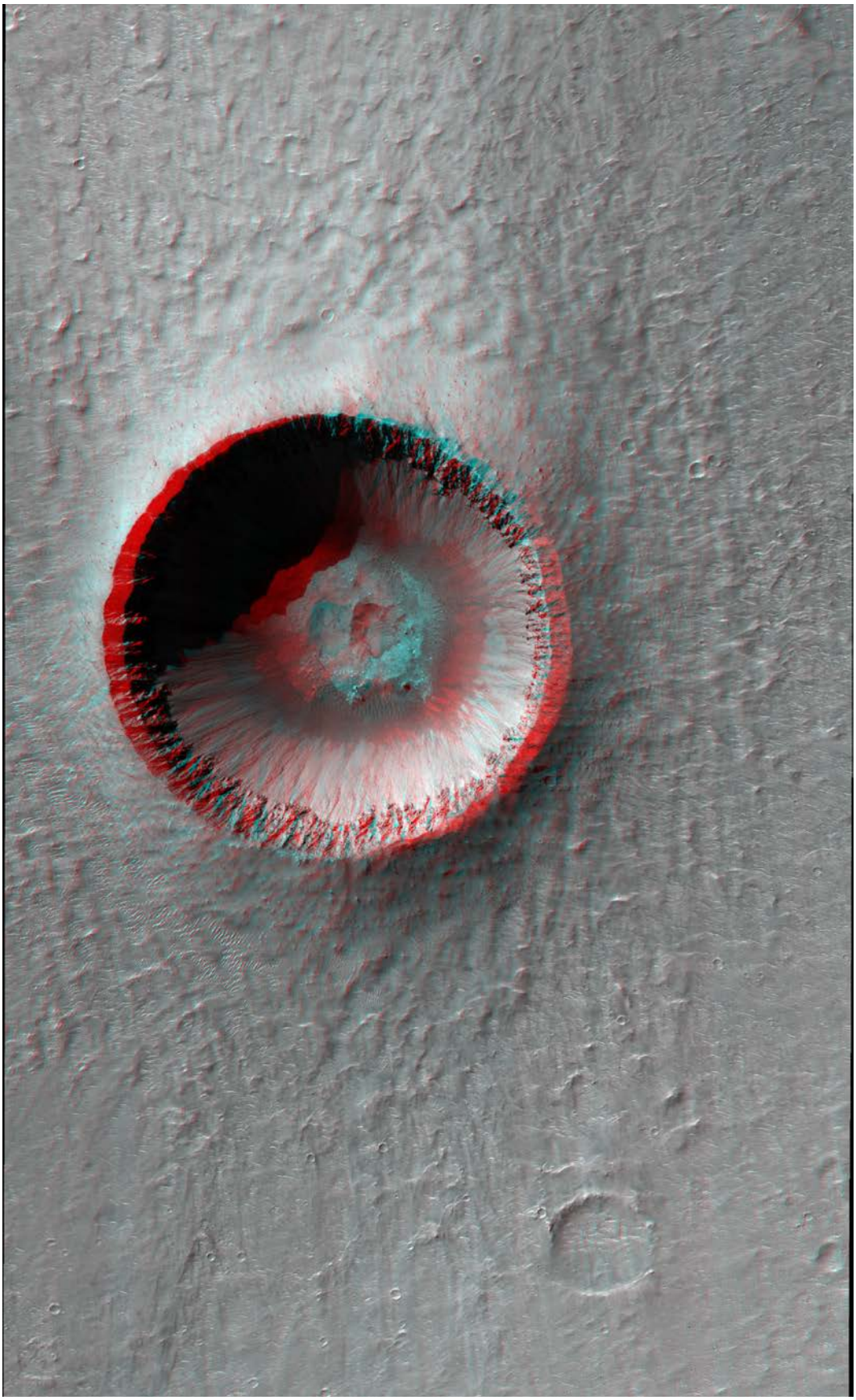
I am uploading details. Maps, objectives, schematics and instructions.

ARCHITECT (internal dialog):

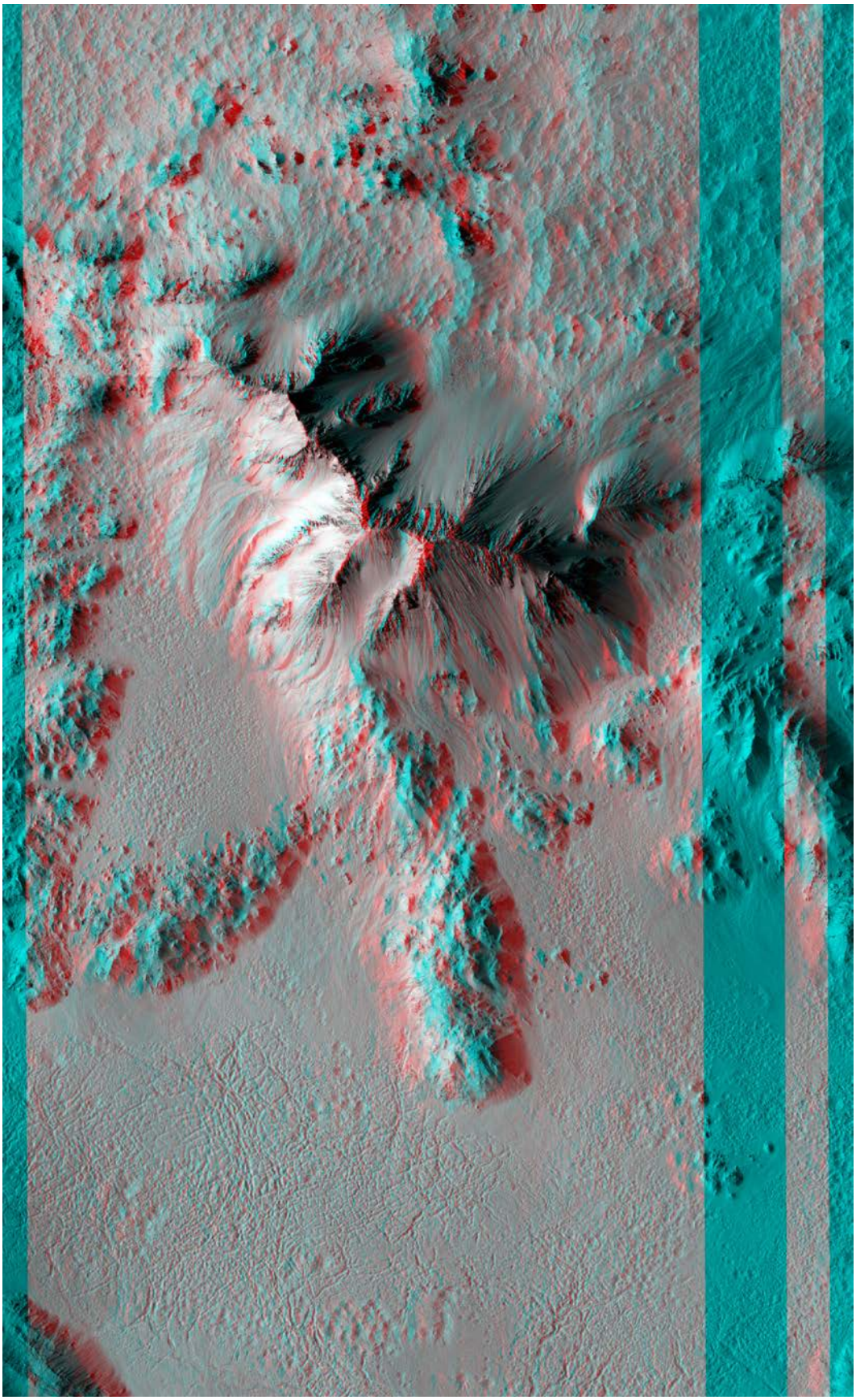
Guess I should move along and see where I end up, maybe I'll find someone or something to help me figure out what is happening.



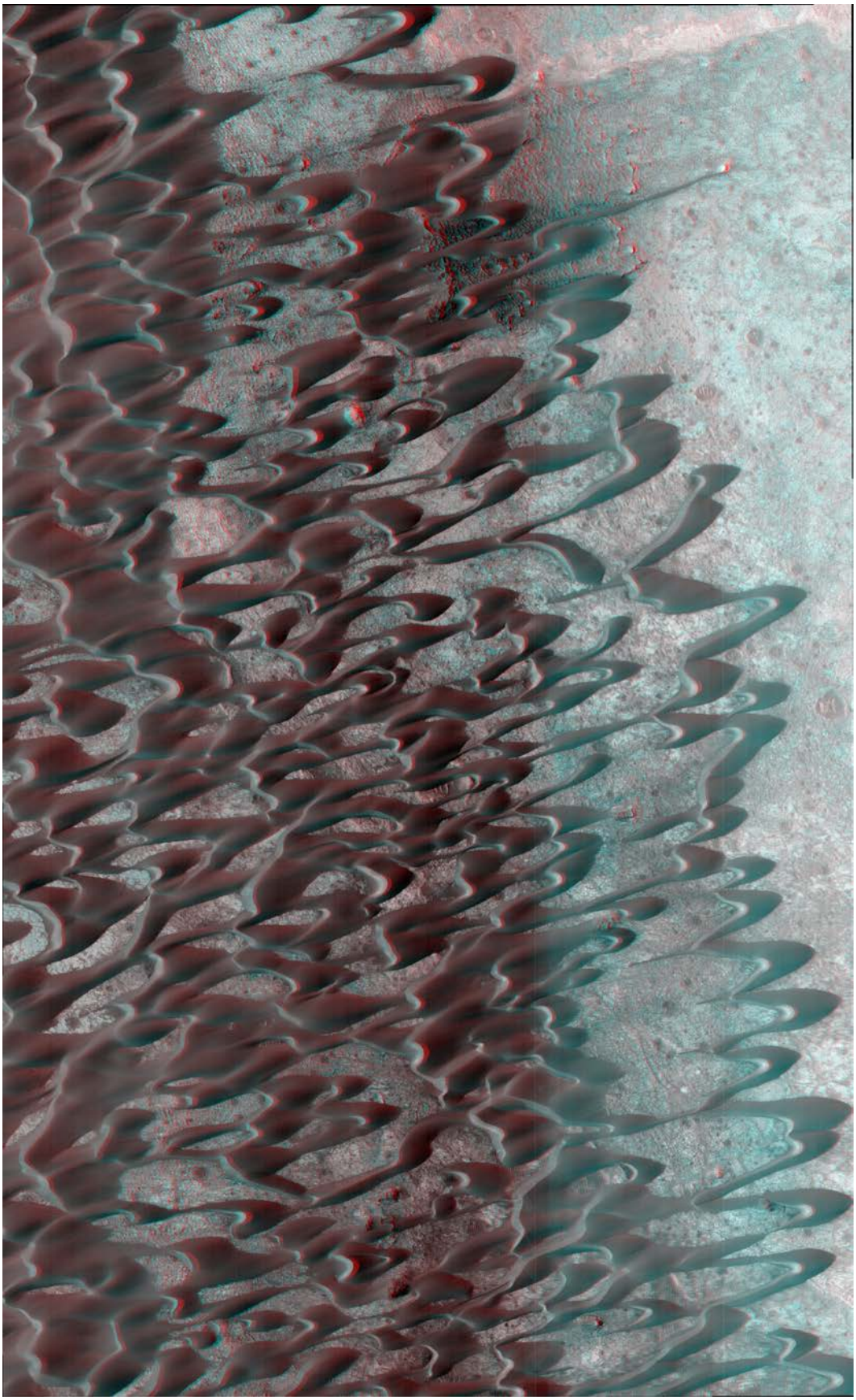
[MCMD B22 location. Map of Mars]



[Margaritifer Terra. HiRISE/ NASA/JPL/University of Arizona]



[Tooting Crater Interior. HiRISE/ NASA/JPL/University of Arizona]



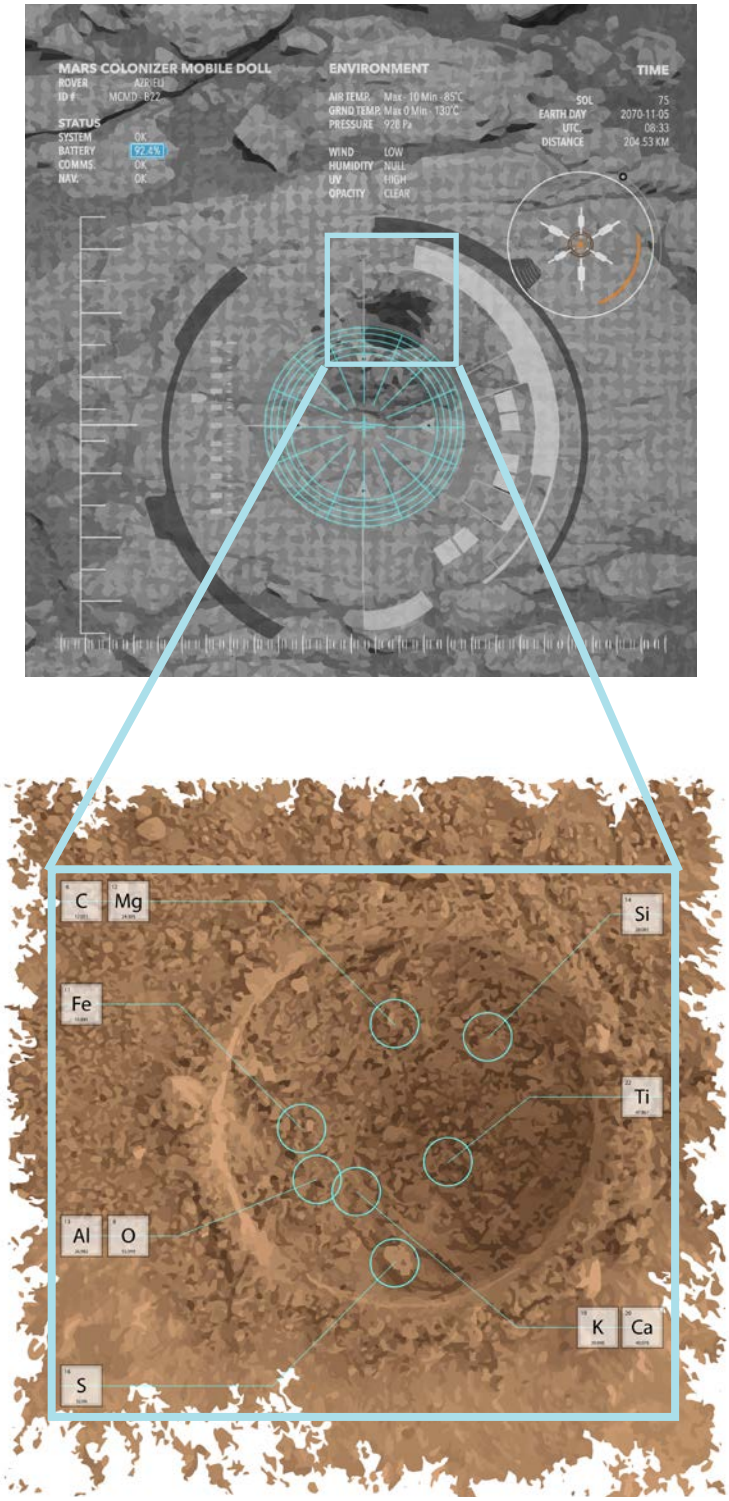
[Nili Patera. HiRISE/ NASA/JPL/University of Arizona]

CONTROL:

MCMD B22, you are approaching site of interest. Take core sample and report findings.

ARCHITECT: (Internal dialog)

Mars. The red planet. Desolate, but calming. Rough, yet soft. The rusted red sand, so fine, microscopic even. The environment is harsh. I can understand why early missions failed. Even if the human body was able to survive the journey through the vast empty coldness of space, they would need months of rehabilitation to get back to normal. Normal being how the body functions on Earth, if that's even possible so far away from home. The atmosphere is weak and mostly carbon dioxide. If the lack of oxygen didn't kill you, the exposure to solar radiation will. The sand will find its way into your body, through the breathing apparatus, or absorbed through your skin. The great dust storms cloak the entire planet in clouds of red and orange haze, resulting in these fierce storms becoming impossibly impenetrable.



[Sample collection of Martian soil for chemical analysis]

ARCHITECT: (Internal dialog)

The topography of Mars is like the Earth's, Mars may be half the size of Earth, but its features are exponentially taller, wider and longer.

Those mountains in the distance, what are those?

CONTROL:

Those are the shield volcanoes of Tharsis Montes. Three ancient Martian Mountain volcanoes formed much like the islands of Hawaii on Earth. However, because the crust of Mars doesn't move like that of the Earth, the volcanoes grew to enormous sizes, by terrestrial standards. To the north lies Ascraeus Mons, the centre is Pavonis Mons and the southernmost is Arsia Mons.

PAVONIS MONS is the smallest of the Tharsis Montes volcanoes, measuring about 375 km across and standing 14 km above Mars' mean surface level. As a shield volcano, Pavonis Mons has an extremely low profile with flank slopes that average only 4°. The summit contains a deep, circular caldera that is 47 km in diameter and almost 5 km deep.

ARCHITECT:

What about the big one behind them?

[Three volcanoes comprise the Tharis Montes;
Arsia Mons, Pavonis Mons and Ascraeus Mons.
Artist Rendering. Kees Veenenbos. Made from Digital elevation
models of the Mars Orbiter Laser Altimeter (MOLA). 2002]

CONTROL:

Olympus Mons. The tallest of the volcanoes on the planet and the tallest on the solar system, standing nearly 22km, roughly two and a half times as tall as Mount Everest's height above sea level.

ARCHITECT:

So, the Space Port is going to be at the top of Pavonis Mons. Control, is there anything else at the top of Pavonis?

CONTROL:

Negative MCMD B22. There are plans for a city to form around the new Space Port. It will be based on the plans for Stardust.

Ascend the volcano and enter the caldera. Drones have begun mining materials within the volcano and In Situ Resource Utilization (ISRU) machine facilities are 3D printing buildings and materials.

ARCHITECT:

For the city that will form around the elevator, upload the master plan. I want to see what a Martian settlement looks like.

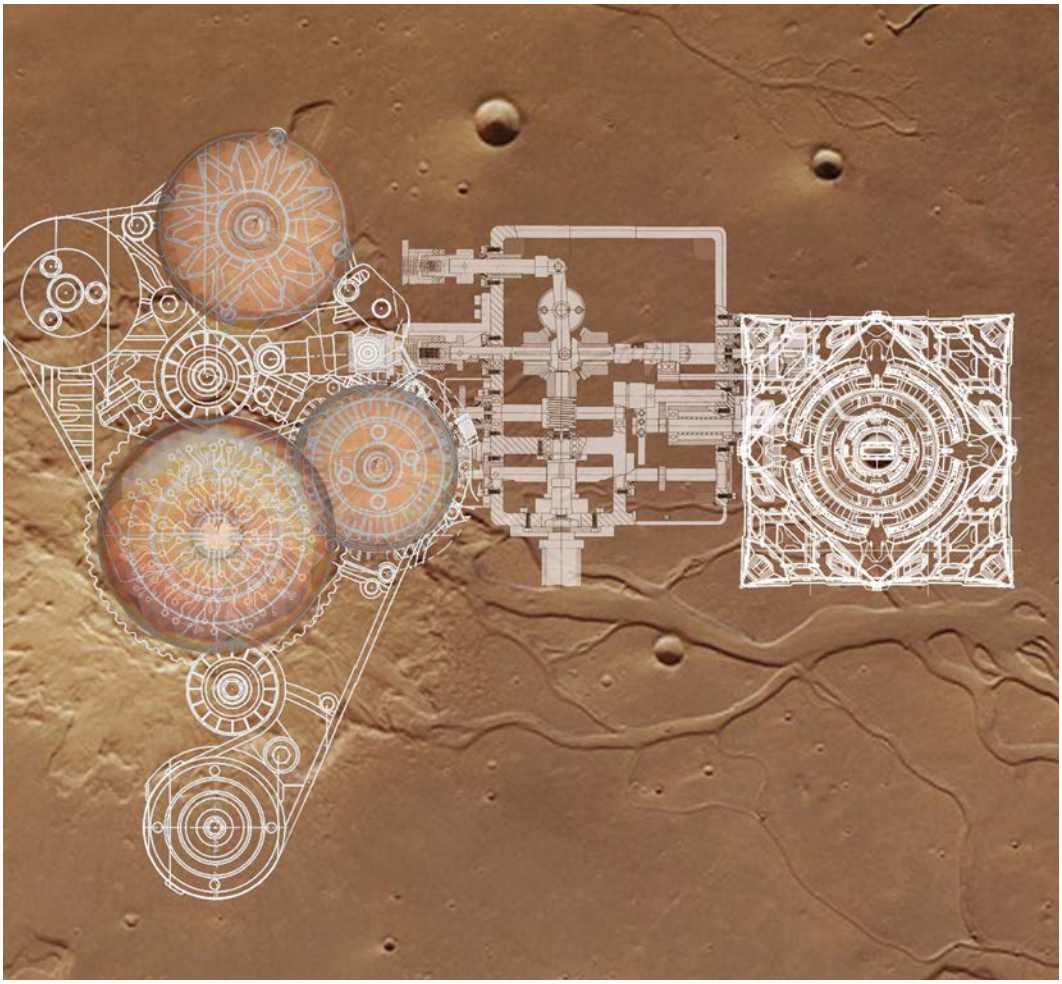
What, No glass domes?!

CONTROL:

The plans for the new city are based upon Stardust. It is the capital of the planet, currently being completed in the Schiaparelli crater.

ARCHITECT:

Stardust? Like Ziggy Stardust? David Bowie's album "The Rise and Fall of Ziggy Stardust and the Spiders from Mars"? I listened to that album only yesterday. I love it! Why and how is it relevant?



[Stardust. Schiaparelli crater]

CONTROL:

In the year 2016, David Robert Jones, stage name, David Bowie passed away. Elon Musk, the man behind SpaceX, the company that first brought humans to Mars, was a fan of Bowie. Pop culture, much like science fiction, has influenced real-world events. Humans find they need to give meaning to everything. Musk wanted to honor Bowie by naming the first settlement in his honour.

The Schiaparelli crater was the site for the first manned landing and has been the hub for manufacturing on Mars. The crater is 460km across and the city itself spans over an area of 200km. SpaceX landed in the crater back in 2024 with their droned ships and in 2026 with the first manned missions of the first hundred. NASA and Mars One landed in 2030. They began construction of the settlement, but all manned missions failed because the travel from Earth was too strenuous for the human body. Whomever remained from the first hundred had to return to Earth or died.

Long before the first manned mission's, humanity was sending rovers to conduct research on Mars. When the first SpaceX drone ships journeyed to Mars, there were no human aboard, only supplies for the manned missions to follow. After the failed human missions, it was decided that drones would once again become the only habitants of Mars. Droned ships would set down on the planet, carrying supplies and armies of robots to begin construction habitats and cities, as well as terraforming efforts.

ARCHITECT:

I can't believe Bowie is dead. Control, play The Rise and Fall of Ziggy Stardust and the Spiders from Mars. The entire album.

…

How can machines build without human input?

CONTROL:

The drones are programmed with an architectural AI; The Master Builder Protocol. Programmed by computer scientists and a handful architects and historians, their A.I. programming is based on the entirety of architectural history. The construction drones construct in real time as the Master Builder drone designs. The drones are left to their own decisions with no human input.

The city is home to drones and the drones are home to the human consciousness that programmed them. They have been building the city for over 70 years. The time of humanity as you knew it is past. The next wave of humanity is on its way. The machines endlessly build, waiting for humanity. They build concrete (3D printed Martian concrete) shells that are based on modules of 3 metres. The AI has determined the architecture of Mars to be a utilitarian design, maximized for functional simplicity with little consideration for how humans interact within spaces and how space affects the people.

ARCHITECT:

Functionalism. Very Bauhaus control.

But architecture should not be of machines. It needs one who understands the relationships between space and form, designs that are imaginative as well as pragmatic. Architecture is an art that works hand in hand with science to design places where people can live, eat, work and play. Machines can't design buildings. Even if man programs the machines, the experiences people feel when they interact with the space they occupy cannot be programmed, or measured, and therefore cannot be accomplished by machines.

ARCHITECT:

Those machines are efficient, but they need direction and adaptability, not simple instruction. These plans are a mess. It works for the drones, but not people. When humanity arrives, they will require comfortable spaces. Homes and buildings that are dynamic in how the user moves through the space. There are health benefits associated with access to public open space such as parks, fields, forests, public squares, and playgrounds are associated with better general health, reduced levels of stress, and reduced depression.

ARCHITECT:

The open spaces and green areas will remind people of Earth and help them with adjusting to living on Mars. After such a long journey through space, they will need familiarity and areas to exercise.

That place is a concrete wasteland. The drones have not considered the human need for green space.

CONTROL:

A new plan for Pavonis Mons has been designed by the collective MCMD-C's artificial intelligence. The Garden City has been determined to be the most efficient and organised plan.

ARCHITECT:

A Garden city? On Mars? Control you're having a laugh, right?

Control, the garden city movement was known for not working well for social connectivity and created isolated communities.

ARCHITECT:

For people to survive on Mars they will have to be able to work together and be close to each other. Cities on Mars must be interwoven layers of different types of buildings and people, not separated industries or vast distances. Density. People helping people to survive.

I feel like there is a better way to plan such a massive and important settlement. Did you look at the great urban planners; Haussmann in Paris, Hobrecht in Berlin, The Eixample by Cerdà in Barcelona, Wagner's Ringstrasse in Vienna, Corb's Ville Radieuse, Wright's Broadacre City?

The settlement cannot be just one urban plan, it must be a mix. Incorporating ideas from all those architects and planners I mentioned. A chimera of urban planning. Learning and incorporating from them their successful design ideas and finding ways to fix their design faults.

CONTROL:

MCMD B22, I don't laugh.

If I may remind you MCMD B22, you were sent to Mars to assist in the inhabitation and terraforming of Mars. Your primary objective is to build the Anchor at the bottom of the Space Elevator at Pavonis Mons.

ARCHITECT:

Show me the plans and walk me through the settlement Control. I want to see if there are any aspects I can improve upon.
Then I will design the Anchor.

CONTROL:

Enter one the BFR ships and interface with the command module on the deck.

The details of the settlement can be viewed and edited onboard the ship. Construction drones can also be controlled via interfacing with the ship.

ARCHITECT:

Thanks control.

Where are those terminals?

Ah. There I think.

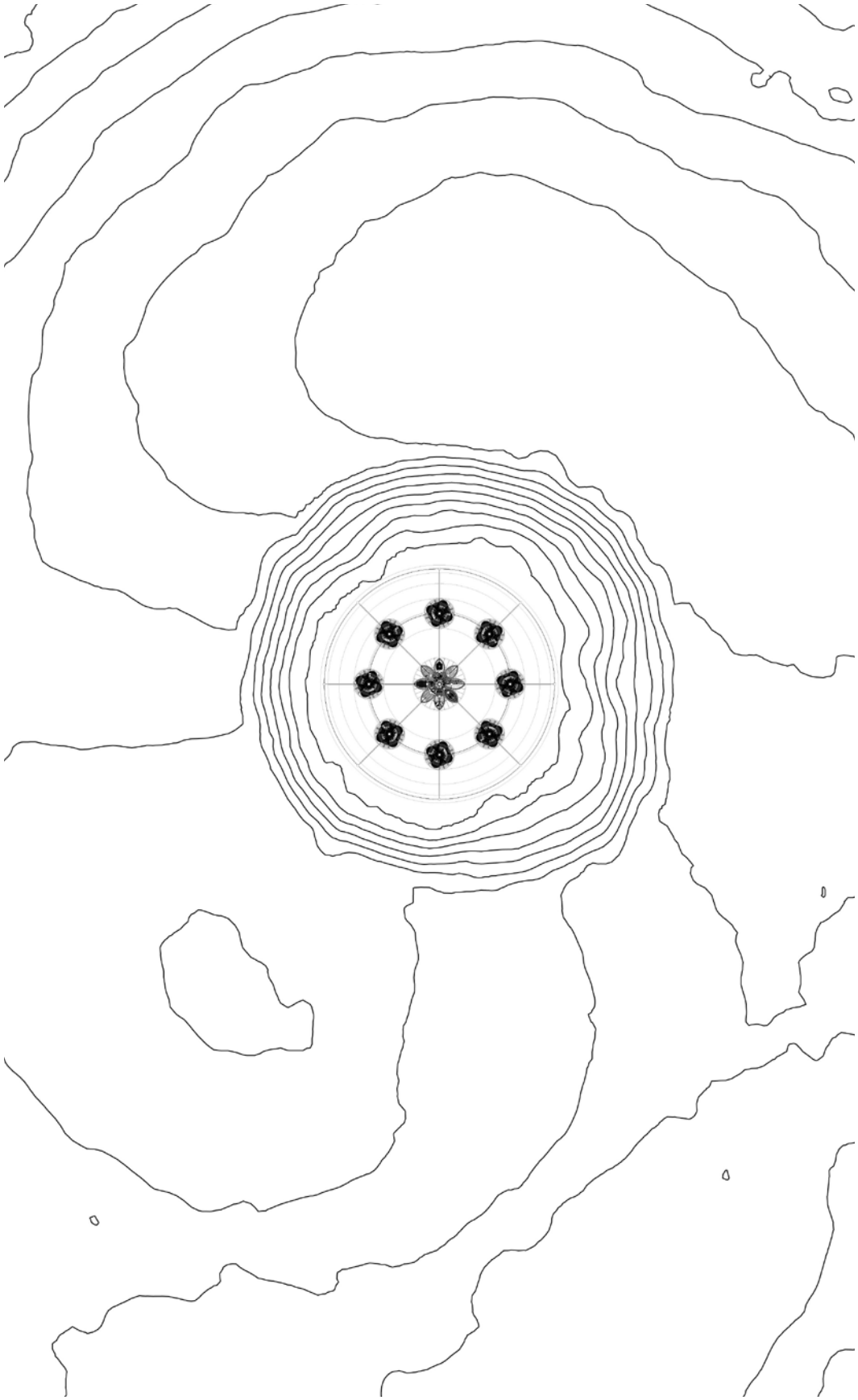
What a fantastic view!

Okay, how does this work?

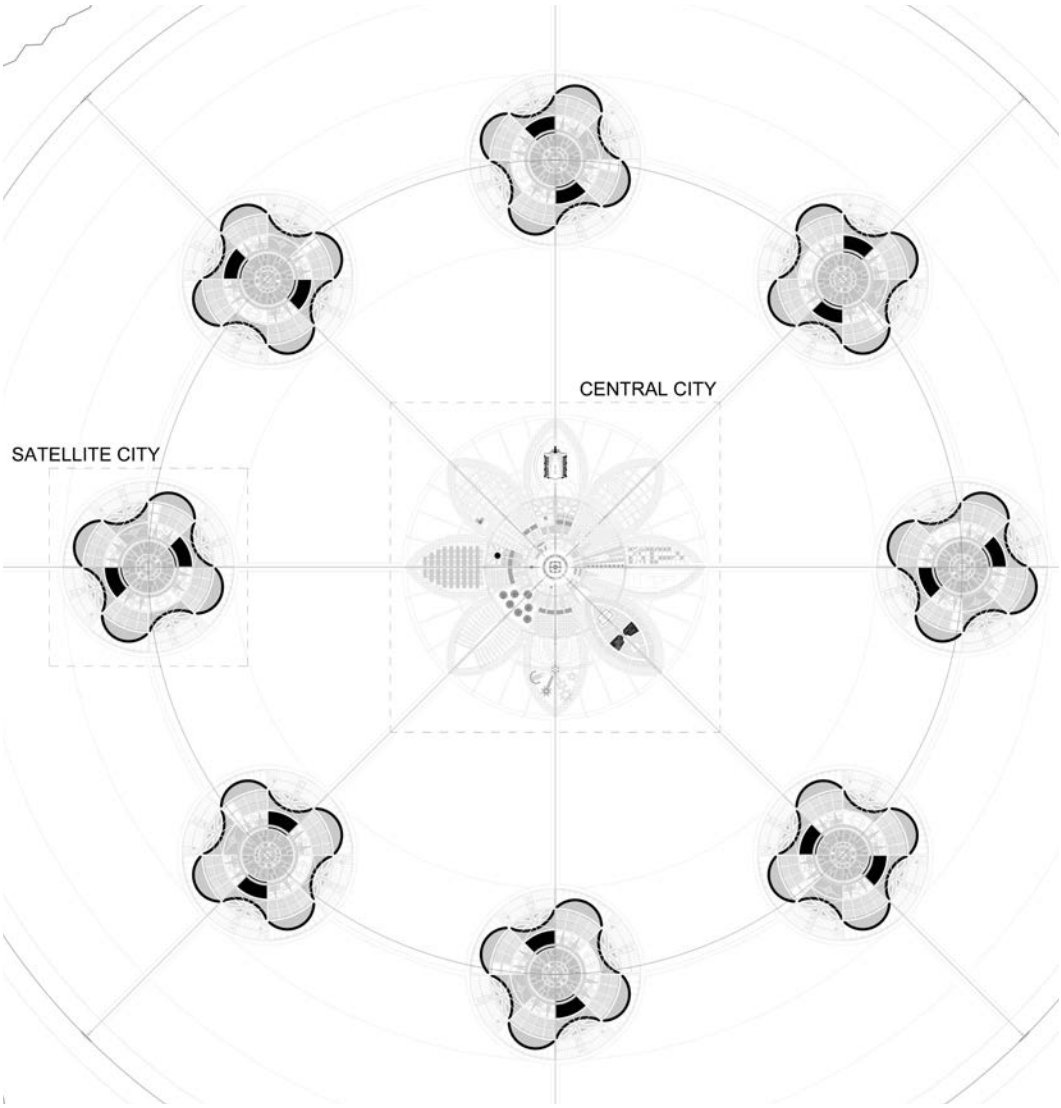
CONTROL:

Mars Colonizer Mobile Doll B22. It has been established that Ebenezer Howard's Garden Cities will be most efficient. The cities will need to be self-sustaining and self-contained within the crater. All industrial processes will happen on the perimeter of the city along the rim of the crater. A train will service the perimeter and make its way into the central city.

When humans arrive to the city there will be a ring of forests, Martian trees. Engineered tree species from Earth. These trees have been modified to grow in Martian soil and will help with the terraforming of Mars. In time the red space will become green space. The city crater is divided into 9 sectors, each sector will be a town. Each town will specialise in certain fields of study or manufacturing and services to work towards terraforming the planet. The 8 towns will be the gates into the city crater from outside the settlement. The 9th town will be the large central city that connects all the towns together and will be the central nervous system for the entire crater. This is where the space elevator will arrive.

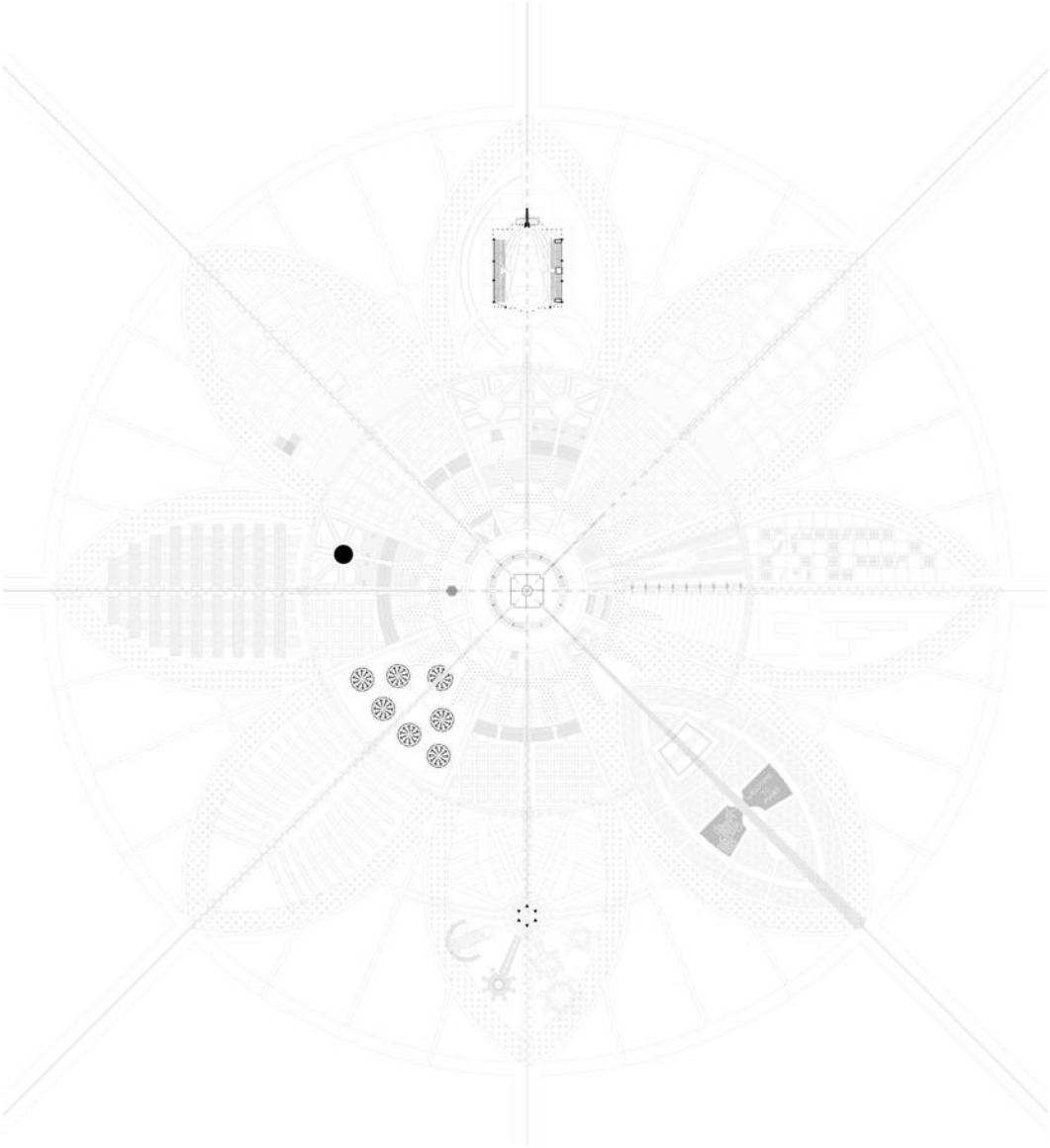


[New Settlement on Pavonis Mons]



[Plan. New Settlement on Pavonis Mons]

[Satellite town. New Settlement on Pavonis Mons]



[Central City Plan. New Settlement on Pavonis Mons]

CONTROL:

A central tower will sit at the centre of each satellite town, concentric circles of mixed use and residential buildings will be divided by avenues of transformation as well as red/green space. Density will decrease as one moves away from the centre. Large agricultural green houses and land dedicated for complex food production will site on the outskirts of the towns, while urban greenhouse towers within the city will provide simpler hydroponic food production.

The central city will be surrounded by a large water way/canal for transport and later it wile be expanded for atmospheric benefits for terraforming endeavours.

The best way to address a walkable city is to put a dome on it. Based on the research from the ISRU facilities, it says new glass panels have been developed to block out harmful UV rays and remain clear.

ARCHITECT:

The dome! I will design the dome!

CONTROL:

Negative MCMD B22. The dome will be geodesic. Efficient and perfect.

ARCHITECT:

The dome can't be a regular dome. It must be as revolutionary as the geodesic dome was. Antoni Gaudí used catenary curves to find the forms needed to design the Sagrada Familia. Gravity was a big part of that. I wonder how the difference in gravity affects such a technique.

CONTROL:

It would be approximately one third of that of the Earth.

ARCHITECT:

Oh right.

I will design a new dome control.

CONTROL:

I cannot allow that MCMD B22

ARCHITECT:

Control, I don't want to have to do this, but I am executing protocol 66.

Full authority to override existing plans.

CONTROL:

Very well MCMD B22.

Please upload new dome designs now**.**

ARCHITECT:

This is real science fiction.

Control, since I was a little kid, I've dreamed of building cities in space.

Thank you.

CONTROL:

Robots cannot dream MCMD B22.

ARCHITECT:

I am not a robot!

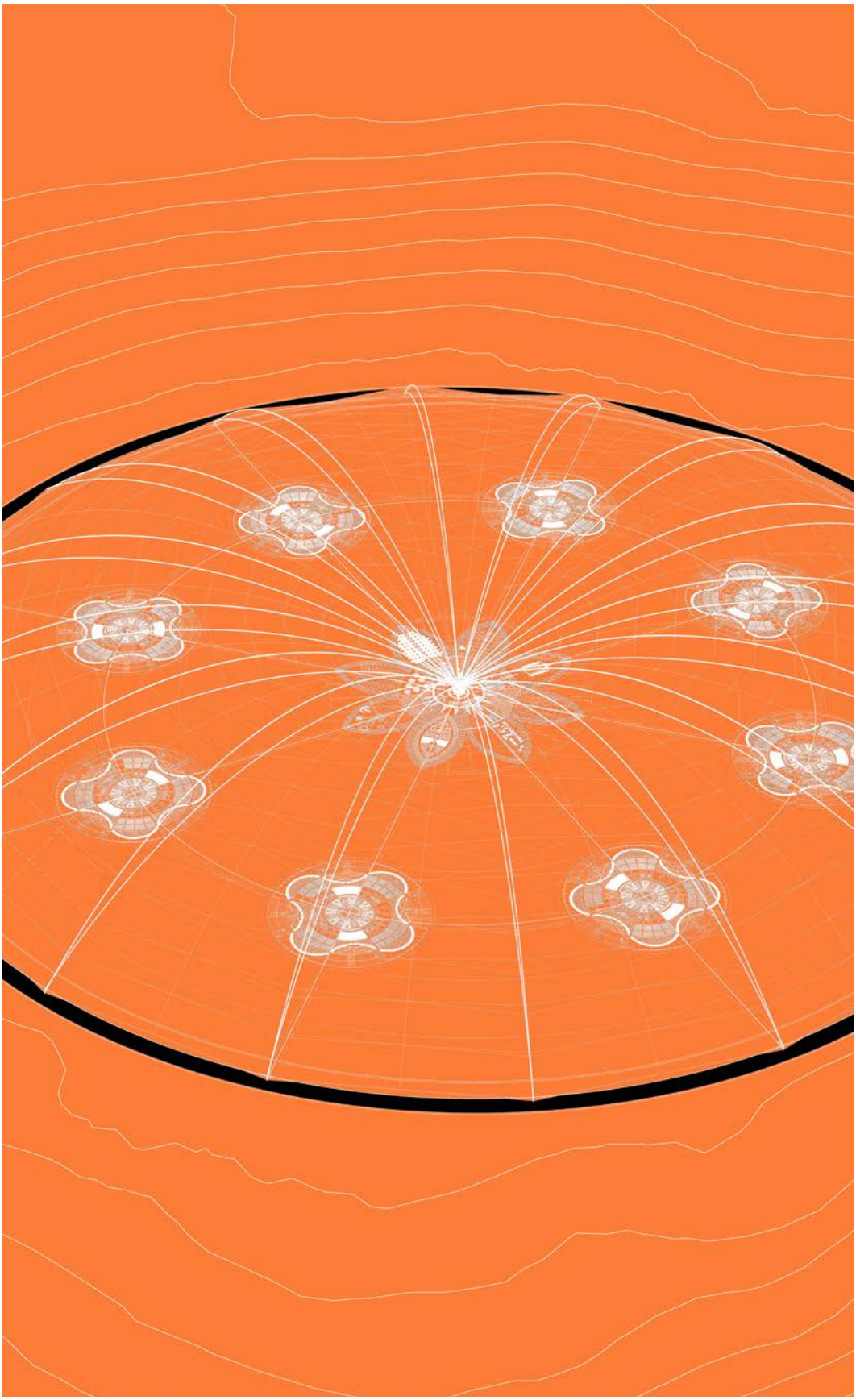
The towers in the smaller towns will act as supports and the Space Port will be the support at the centre of the dome. To keep the city air tight, the dome will appear to be sprouting out from the top of the elevator creating an opening at the summit, giving it the distinctive ring shape of a Bundt cake.

The domes ringed cross section will act as supports so theoretically the towers might not be needed as supports. And the sections will also act as bulkheads that can potentially be closed in case of a breach.

The Anchor will sit at the centre of the caldera. It should be unique to the planet, something completely alien to Mars, something that doesn't appear natural here; a perfect cube. Like placing a square peg in a circular hole. The presence of the cube will show whoever is out there that humanity is a multiplanetary species.

The perfect cube contrasting with the Martian terrain will give a sense of beginning and termination. It will be a beacon for travellers trying to find their ways home to Earth.

The Anchor will be like the Tower of Babel. The elevator will unite humanity as we expand our species into the universe to gain more knowledge and find ways of relieving the use of resources on Earth as we run out of them. Humanity is working together to reach Mars, different countries and religions are setting their history of violence aside to further humanity and succeed together.



[Dome over New Settlement on Pavonis Mons]

CONTROL:

MCMD B22. Your perception of the Earth is incorrect. The Earth is fine. The climate change has halted, the Earth's atmosphere has been repaired and is as healthy as it was before the start of the 20th century. Jump back to the beginning of the century, after only a year as president, Donald Trump was overthrown by a coalition of scientists. They infiltrated major governments around the world in non-violent and unbothered events that were publicly endorsed because the Earth was on its last legs. The World Science Coalition united the super powers of the world and began a cleaning campaign that saw the end of nuclear weapons, nuclear power and its waste, and the end to the use of petroleum and fossil fuels. An incredible increase in the development and dependency of renewable energy ushered in a wave of prosperity both environmentally and economically as new industries formed from the development of new technology; a type of industrial renaissance.

ARCHITECT:

Then humanity is fine?

CONTROL:

Yes and no. Over population and limited resources means that humanity needed to extract resources from asteroids and other planets. The over population on the Earth is a result of advancements in medicine. People are living longer while food supplies, resources, and open space is dwindling.

Space agencies and governments decided to begin migrating people off the Earth and to expand to Mars. Most people are volunteers. Expert scientists and engineers are among the first migrants and will be training the volunteers and leading the settlement efforts.

ARCHITECT:

Wow. A lot has changed since 1972. I was under the impression that humanity was doomed on Earth and had to escape to Mars.

So now that the city has been planned, lets begin to redesign the Space Port. The gravity on Mars is 1/3rd the Earth's, that will affect how long spans for beams will be. I want to illustrate the fact that there is less gravity. How can I make the Space Port appear to be floating?

A space frame tubular steel structure. The decreased gravity allows for smaller steel members to span the same distances. The whole building can be lifted into the air with minimal supports. The cables and dome will assist in keeping the Space Port off the ground, hanging like a curtain wall.

The elevator cables will be anchored deep into the planet. People will be able to walk under the Space Port and see the massive cables run deep into the heart of Mars.

Control, what is the status of the space elevator?

CONTROL:

The cable has been completed and is floating in space at the edge of the planet's atmosphere.
It is 17,000 km long and 10 meters thick, weighing 3 billion tons.
The space station at the top of the elevator is named Clarke, after…

ARCHITECT: (interrupts CONTROL)

Arthur C. Clarke? The great science fiction writer?

2001: A Space Odyssey is my favourite movie.
I'm glad that you haven't turned out to be like the HAL 9000 in the movie.

CONTROL:

Correct, Arthur C. Clarke.

I am unfamiliar with that reference, "Dave".

ARCHITECT:

Good one Control.

CONTROL:

The top of the Space Elevator is the space station Clarke, built on/ from the remainder of the asteroid the massive cable was made from. Elevator cars will travel up and down the cable at 400 km/h making the journey from just out side Martian orbit down to the surface in 2 days.

ARCHITECT:

The primary spaces of the Space Port will be the vertical platforms for the elevator. It should have the resemblance of an airport terminal, providing all the basic amenities of an airport on earth: passenger processing and facilities, security, baggage area, meeting areas, offices and even temporary dwellings.

For travellers ascending the elevator, they will enter from beneath the floating structure. They will enter the dramatically massive open departure hall, which will prepare them for the vast emptiness of space travel, and when their "flight" is ready, climb the elevator to depart the Red planet and ascend into space.

As passengers make their way past security check points and ascend to the platform gate, they can shop, relax, and enjoy their remaining time on Mars. Cabins for temporary, or long-term stay will be available on the upper levels for travellers. For new arrivals, they can wait in the temporary housing until their accommodation is ready.

ARCHITECT:

The top level will be the control centre of the Space Port and city. All services; mechanical, plumbing and emergency stairs will run inside the framing at the four corners of the building.

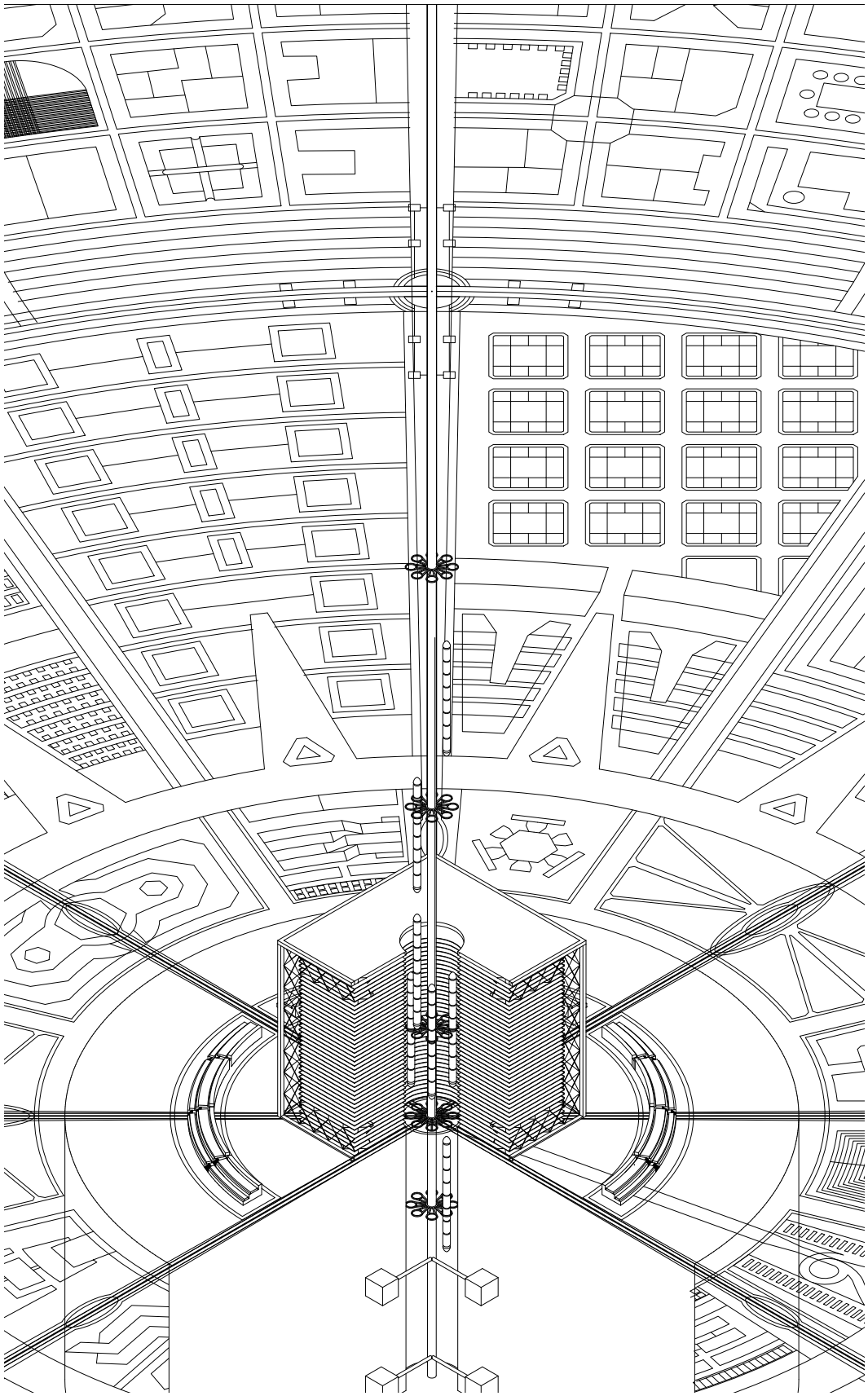
In the lower levels; sitting behind the structural space frames will be the baggage area. Below grade will be the heavy loading area where raw materials and heavy equipment will travel between Mars and the Earth. A city with such an important transportation hub must be planned to accommodate large movements of people, both in the Space Port and within the City. And if the city will be a hub for transporting goods there will need to be large staging and storage areas.

The aim of the design is a play with gravity and scale. Not only will travellers feel the difference in gravity, but the architecture will illustrate how people must adapt to a new "normal" in their daily lives.

The enormous scale of the Anchor Port, the projects that follow and the projects that predates the Elevator will be massive undertakings that require the cooperation between disciplines and experts towards a singular goal: human prosperity on Mars.

Getting to Mars alone, a journey spanning 140 million miles, is such a massive engineering feat. The space port and the architecture should give the sense that the scale on Mars will roughly be three times that of Earth.

The scale of the craters and volcanoes are out of anything ordinary. We see them as soft rolling hills only a couple of kilometres in diameter and hundred metres in height, however they are like mountains stretching across continents and reaching the heavens. The geological features on Mars dwarf their Terran counter parts, sometimes doubling, or even tripling the biggest features on Earth.
There is a lot to do Control, better get started.



[Space Elevator Anchor]

CONTROL:

MCMD B22, mining drones have begun excavating, extracting and stockpiling materials for the cable anchor hole and lower levels. ISRU facilities are operational and begun producing materials.

…….

ARCHITECT: (internal thoughts)

As Control was listing off all the work completed by the drones, the thought of finding out what happened to me never crossed my mind. As a child I would stare up at the stars at night, wondering what might be out there, what other worlds might be like. As an architecture student and later as a practising architect, I would find myself doodling cities described in science fiction stories. Cities never sleeping, buildings that reach for the stars, flying cars, robots used for everyday life, devices from Star Trek that people can use to communicate to each other anytime, anywhere.

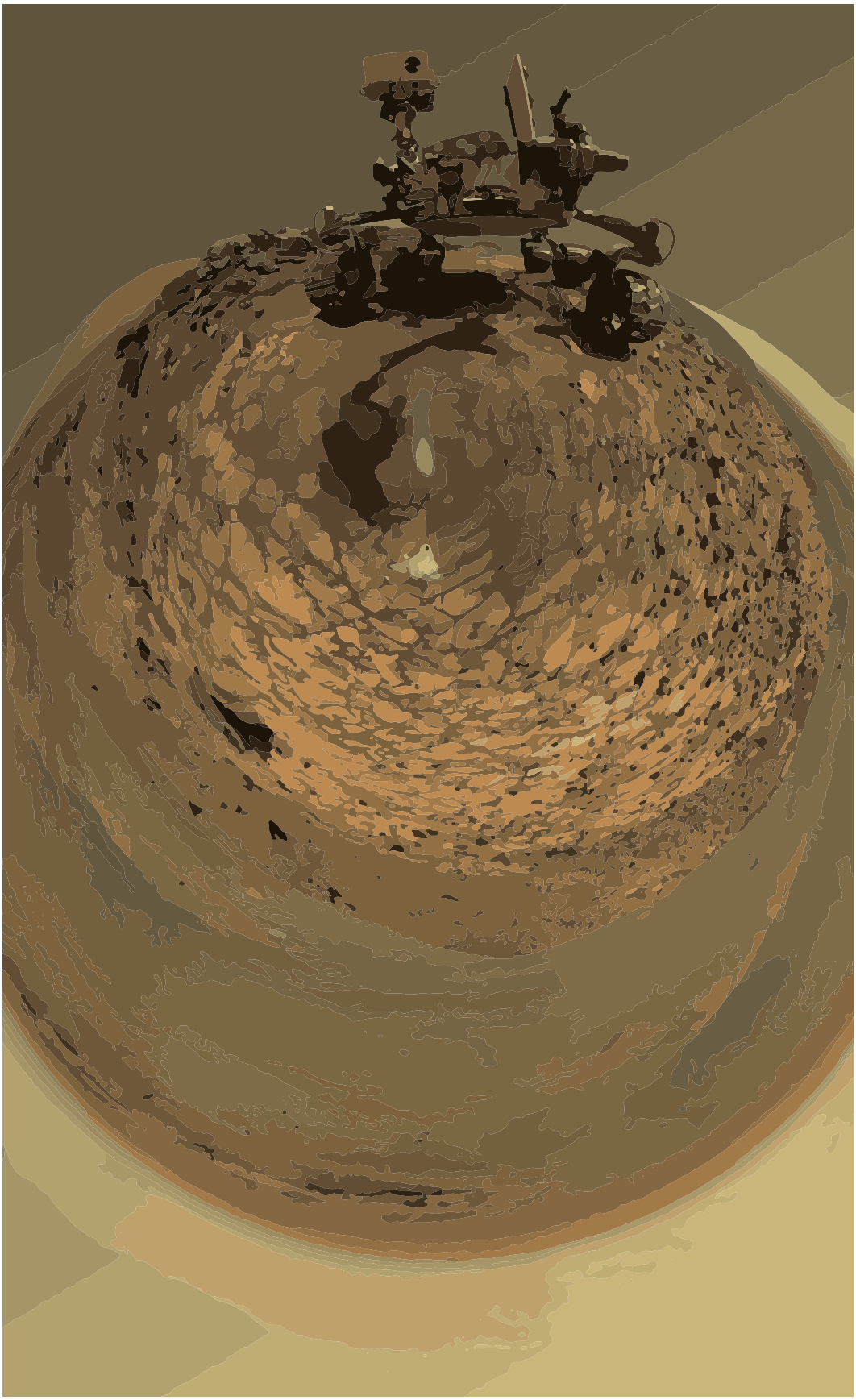
Now that I am here, in the supposed future, fulfilling my dreams, I want more. I want to write and live my own science fiction. I may be stuck here, not to ever find out what happened, or how I got here. It will remain an unsolved mystery. Or this could be a dream.

ARCHITECT:

Control, keep me updated on the progress of construction.
I would like to continue my journey on Mars, survey the next settlement, or go to Schiaparelli and fix Stardust before it is too late.

ARCHITECT: (internal thoughts)

I left the control terminal on the bridge of the BFR, I caught a reflection of myself in the ships panelling…



[Reflection of MCMD B22 in panel of BFR Starship]

BACK ON EARTH,

"Medical Logs. The Diary of Dr. Eir and the first hundred's journey to Mars" were written as a prequel narrative to **"A Journey of a Robotic Architect"**. It further explains why manned missions to Mars failed and cancelled, then replaced by robotic missions.

These medical entries discuss the affects that space travel has on the human body, seen through the eyes of the Doctor on the first settlement ship sent to Mars in the year 2025. The entries sketches are her daily accounts of what she experiences on the journey to Mars.

MEDICAL LOGS.

The Diary of Dr. Eir, and the first hundred's journey to Mars.

[A prequel to the main narrative, "Journey of a Robotic Architect"]

“

MAN IS NOT MADE FOR SPACE

// Wernher von Braun, A Primer of Space Medicine, 1960

”

MEDICAL LOGS.

THE DIARY OF DR. EIR, & THE FIRST HUNDRED'S JOURNEY TO MARS.

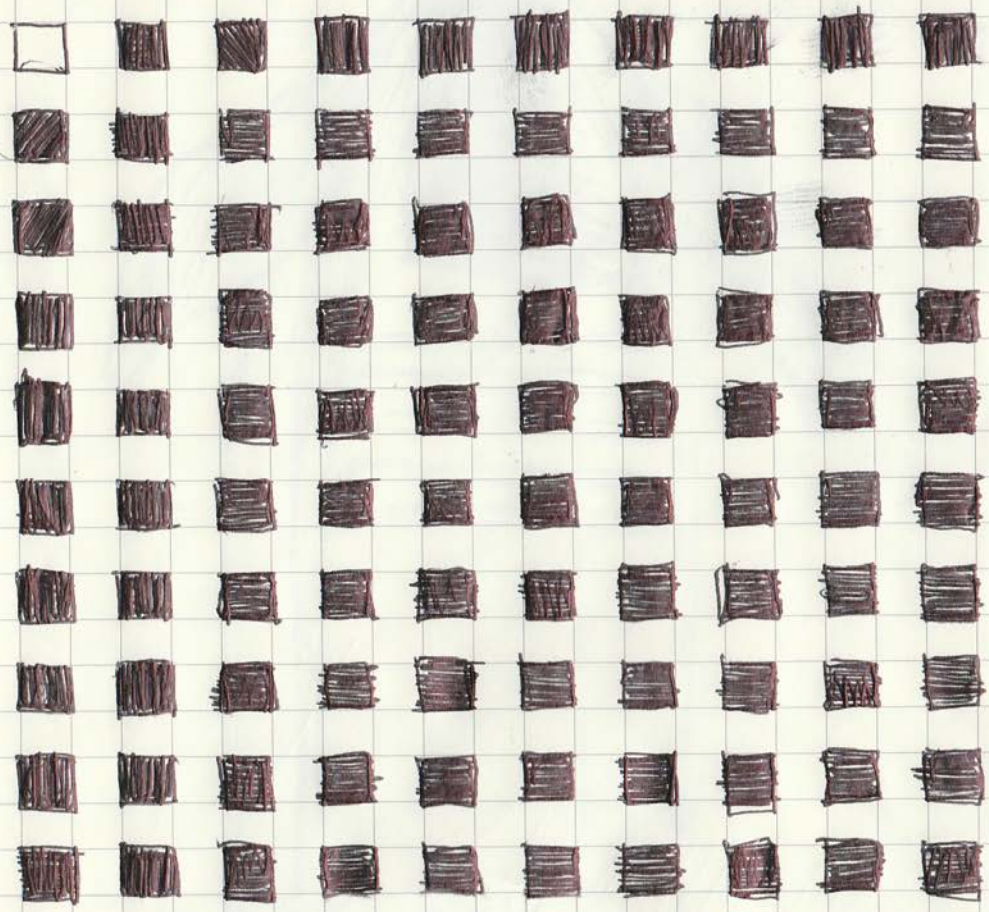
\\\\ A PREQUEL TO THE SCI-FI NARRATIVE

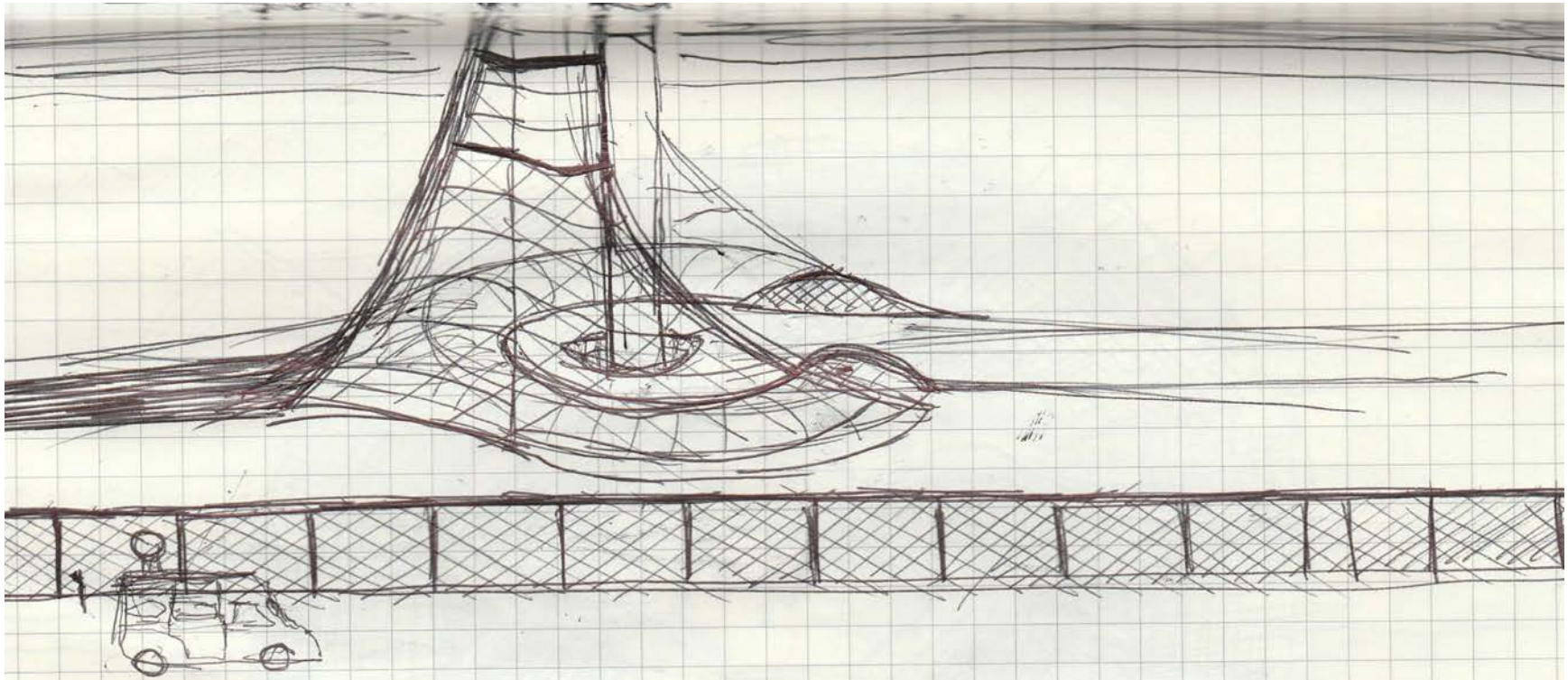
2025, the third manned mission to Mars has taken off in the Heart of Gold, a SpaceX BFR starship, funded by NASA and MESEA (Mars Earth Space Exploration Administration), carries 100 of the worlds leading scientists and engineers. The grueling journey will take the first hundred across 480 million kilometres of space, the furthest manned space flight in history. Astronauts have survived in space for longer but have returned to the familiarity of our Earth gravity. Landing on Mars will be challenging enough for the settlers and if they are not at 100% health, what additional challenges will they face?

MEDICAL LOG 2025.09.13 DAY -004

This is my first entry. My name is Dr. Astrid Eir, Chief Medical Officer aboard the Heart of Gold. This mission is the largest manned mission to travel to the planet Mars, with 100 crew, our mission is to explore the planet and begin settling efforts on the planet. As the Chief Medical Officer, I oversee the health and wellbeing of 99 crew members. As the final checks to the Heart of Gold are underway, I was checking the medical bay's systems and supplies before the rocket is placed in its booster stages. My mentor, Dr. Leonard McCoy, had mentioned to triple check the supplies for the journey to Mars and ensure that they were enough to last until the next supply ship, he says you can never be overprepared for space.

I came across a strange undocumented cargo container that would not unlock with my access key. It was in a red container with a white cross on it, obviously medical cargo. I tried another container, which worked. Whatever was in the other container, was above my pay grade. I left and reported it to the Chief Operator. I don't think anything will come of it, they were too busy making the final preparations.





MEDICAL LOG 2025.09.15 DAY -002

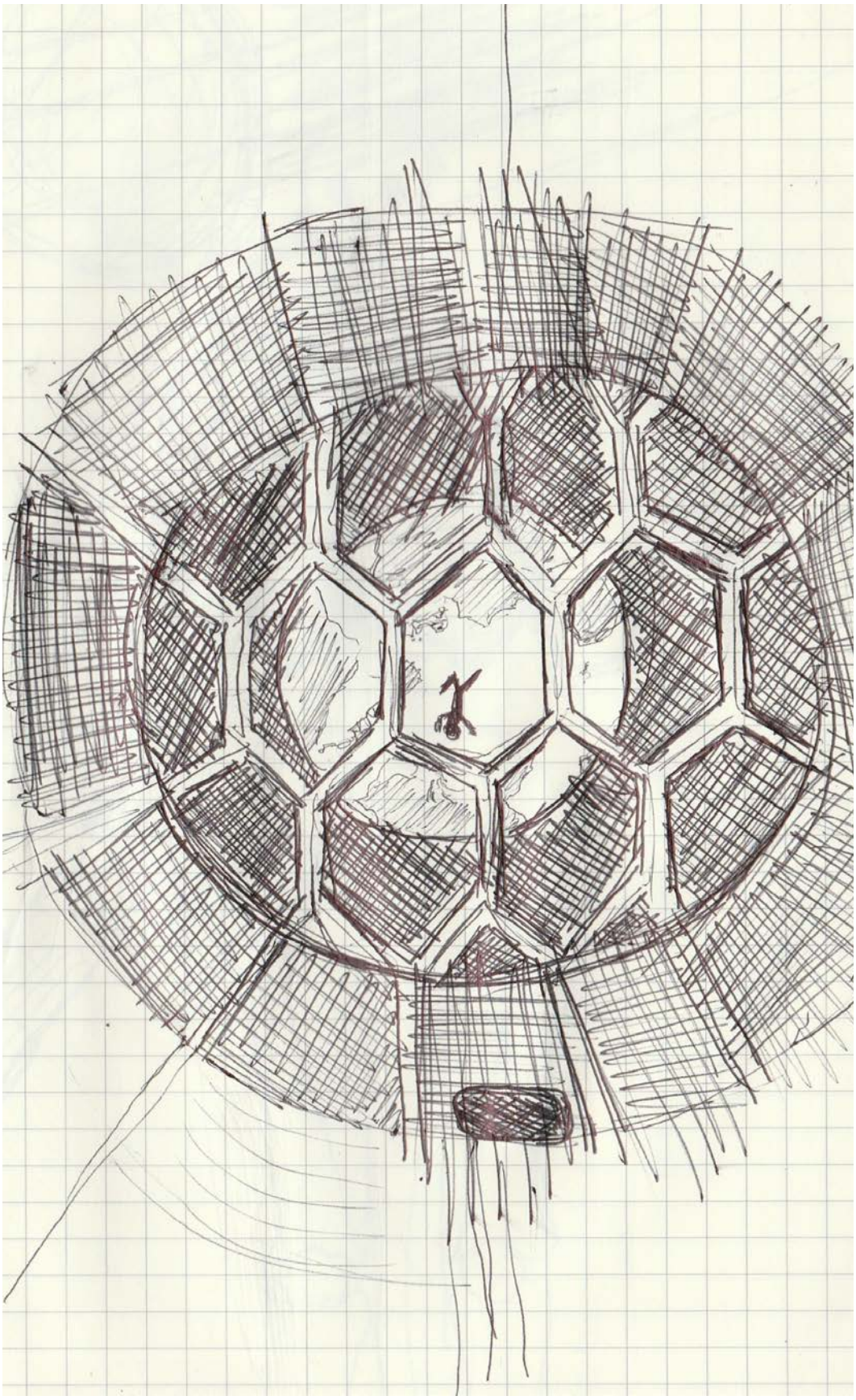
The launch was scheduled for today but has been delayed because of a weather system coming in from the Atlantic. This coastal weather can be nasty. Mars is said to be dry and dusty. It will be a long time before I see an ocean or rain again. I sure will miss it. Especially the snow.

MEDICAL LOG 2025.09.17 DAY 000

Today we lift off. My next log entry will be in space.

MEDICAL LOG 2025.09.18 DAY 001

We made it, we are officially in space. This feels different from the zero gravity training aircraft, the Vomit Comet. This being the first time into space for many, I was treating crew members for nausea all day. Some were experiencing headaches, because of pressure build up. Nothing severe.



MEDICAL LOG 2025.09.24 DAY 007

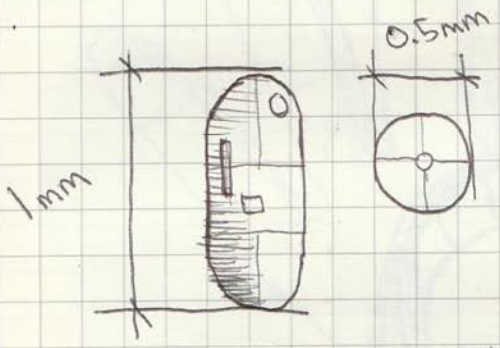
Our first week of space has been a success. The flight crew took a trajectory around the moon to use a slingshot to gain speed before we left home for good. We were lucky to see the Apollo 11 landing site. As we rocket to Mars at about 20,000km/h there have been no issues with the ship. We did hear a bang, but visual inspection showed it was nothing to be worried about.

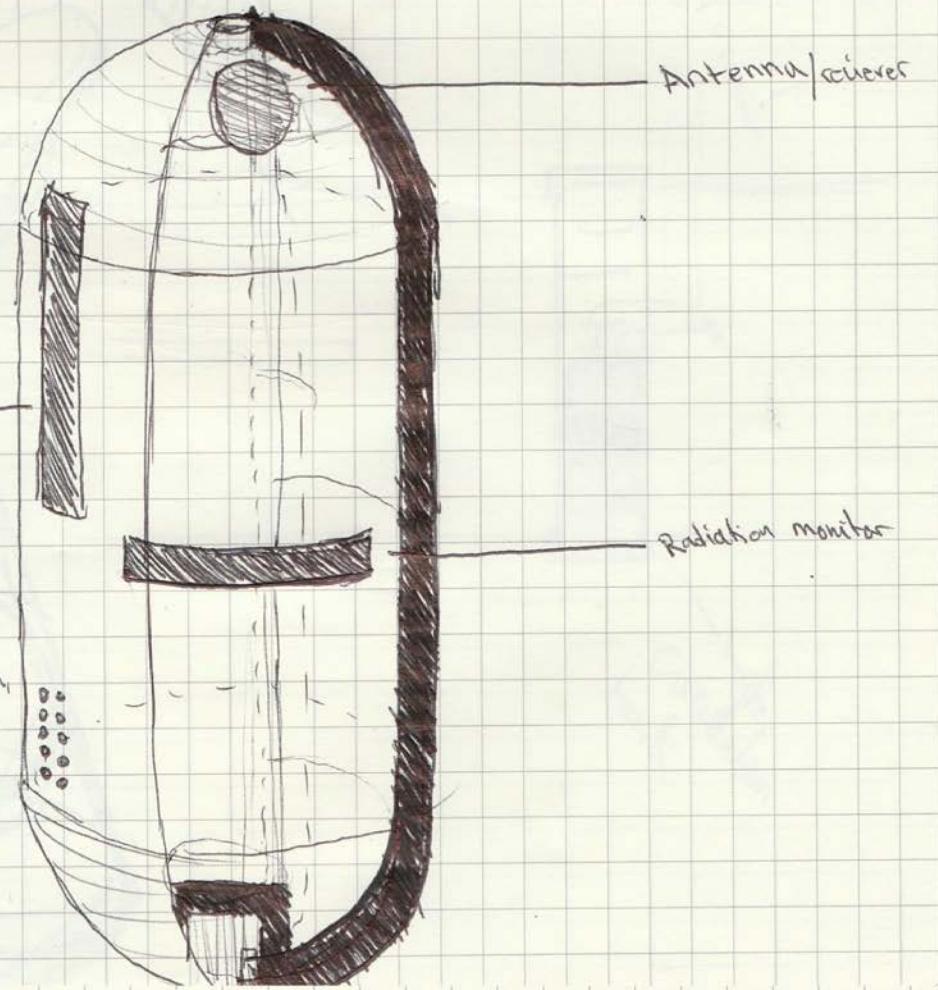
NASA and MESEA medical protocol states that I must do the first round of crew tests tomorrow. I will be taking blood for CBC tests, echocardiography, bone density study, and mammogram tests for female crew and prostate tests for male crew members. These tests will be compared to their test conducted on Earth and monitored during the voyage. Each crew member will go through these tests once a month. NASA issued new health monitors, which will be commissioned to the crew after the first test. It's a small device that gets injected under the skin. It will then be synced to my work station in sickbay and feed real time information regarding the health of each crew member. And if there are issues, I will be notified on their status and their location on the ship.

.

MEDICAL LOG 2025.09.30 DAY 013

It took me 5 days to test the crew and implant monitors. Everyone seems fine so far. Almost 2 weeks into our voyage and you can see groups forming among the crew. We trained together on Earth in the isolation field research centre in Hawaii, which wouldn't have been a bad place to be isolated, but in order to simulate being on Mars, we were at the top of volcano and couldn't leave out habitats without full space suits on. I was hoping to get a tan whilst there. The mission in isolation was to see how we would cope with each other in isolation as these people will likely be the people we spend the rest of our lives with.





Function: implant injected into bloodstream, attaches itself to heart and spreads micro-monitors to extremeties of body.
Antenna/recievers transmits data to sickbay, location trackers, in emergency protocol, can stun patient/crew if deemed unsafe.
Radiation monitor detects nuclear particles or radiation in the human body.

MEDICAL LOG 2025.10.08 DAY 021

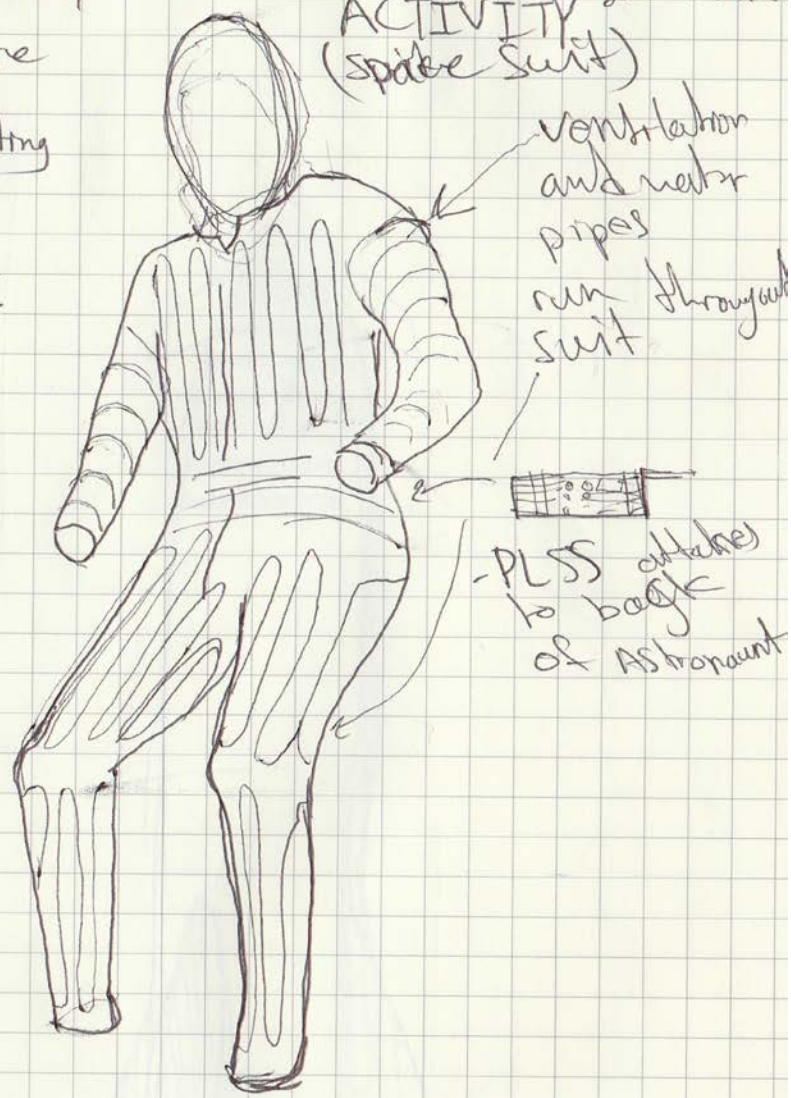
The journey has been uneventful so far. The crew is healthy and functioning at 100%. Everyone gets 2-6 hours of exercise a day, as ordered by NASA.

Meals are packed with nutrient enriched foods to boost the bodies intake of vitamins and minerals as solar radiation is constantly bombarding our cells. Each crew member carries water packs on their backs to keep hydrated.

Flight suites are lined with piping that circulates warm water around the body for warmth and to keep blood flowing around the body. Water is also the best shield for radiation, so the suites also act as personal shields. Someone came in complaining about vision problems. This is due to fluid build up in the head, which applies pressure to their eyes. Someone else came in with abdominal pains. Going to the washroom in space is a tricky matter, the crew member had not evacuated their system for several days. I gave them a mild laxative and their pain went away in a day. The toilets are different to those on Earth, because the water would float everywhere. No water is used, it is all vacuums and moist towelettes. Someone at SpaceX thought it would be funny to post copies of the Zero Gravity Toilet instructions from 2001: A Space Odyssey in all the toilets, trying to confuse the crew. It is surprisingly detailed, but that system doesn't even exist in the real world. Good one Elon!

LIQUID COOLING AND VENTILATION GARMENT (LCVG) is part of EXTRAVEHICULAR ACTIVITY (space suit)

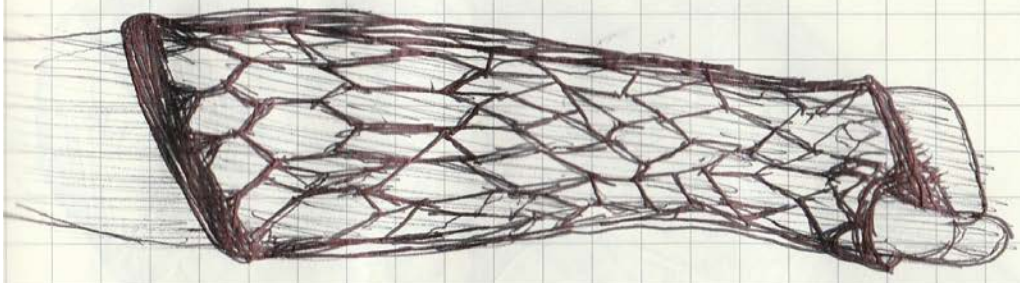
- regular body temperature
- form fitting
- Part of PORTABLE LIFE Support System



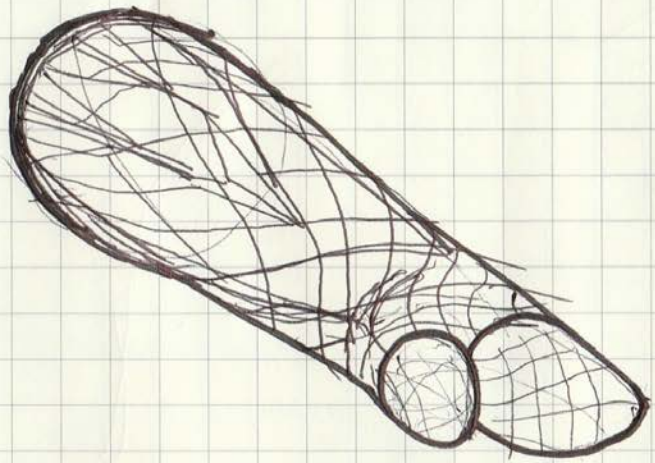
MEDICAL LOG 2025.10.12 DAY 025

There was an accident today. One of the airlocks malfunctioned and closed on someone's arm. Luckily the doors closed on a part of the space suit that couples two sections of the suit together and protected him just enough that the arm was only broken and not severed completely. What a mess that would have been… it would have been almost impossible to stop the bleeding. The blood would float everywhere. I was able to 3D print them a cast, but I'm not sure when or if his arm will heal. Typically, a broken bone would heal between 6-10 weeks on Earth. In space, it could take double that maybe? There has never been a broken bone in space before, it will be great research to see how the bone heals. Great for NASA and space medicine research, but unfortunate for the crew member.

3D printed cast



- Easy to form
- exact fit
- breathable
- fast to make



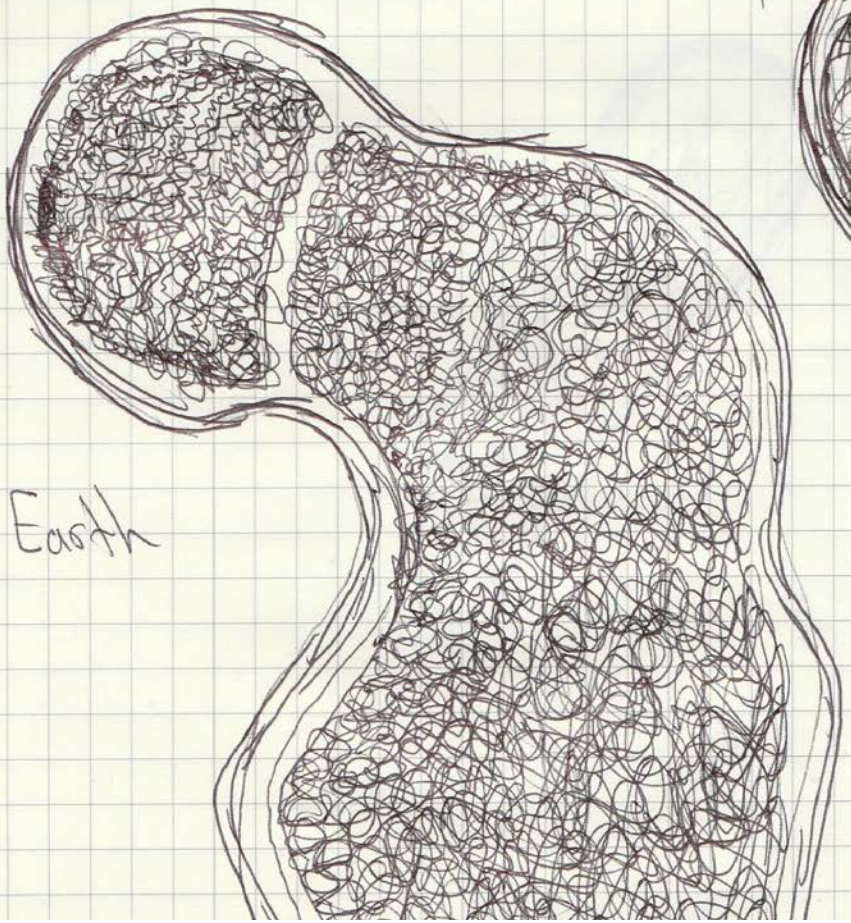
MEDICAL LOG 2025.10.20 DAY 033

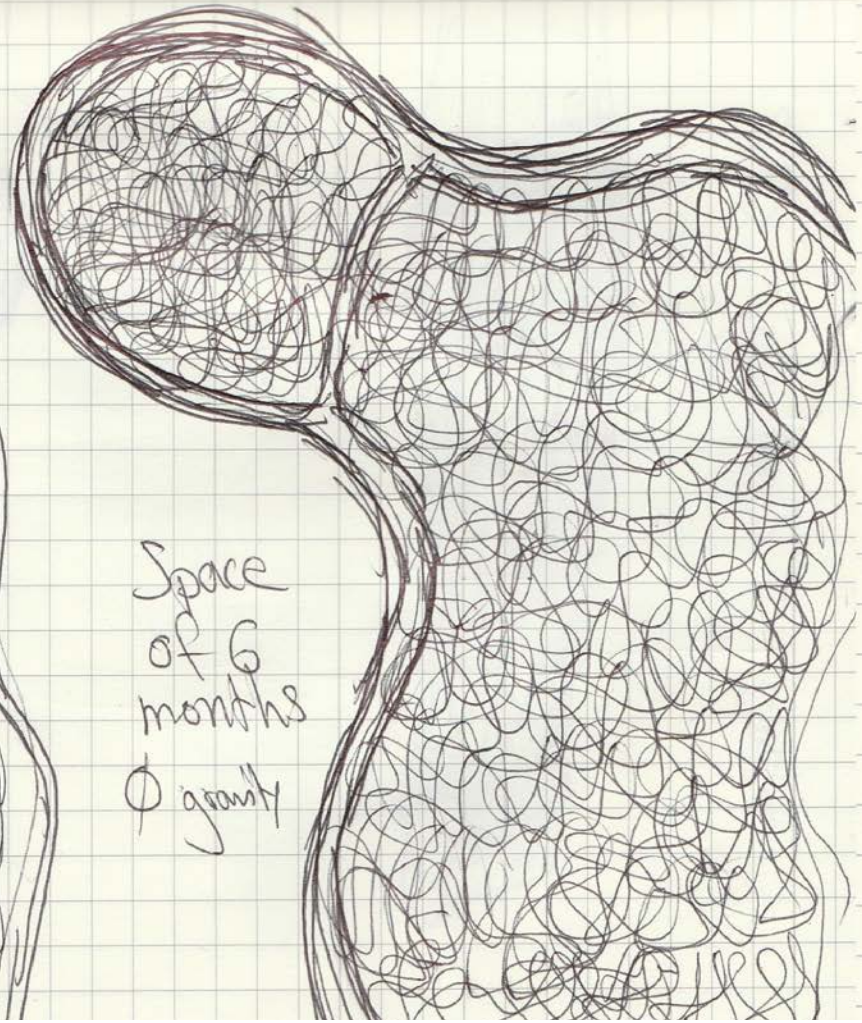
We are now a month into our journey. The only major incident being a crew member with a broken forearm. After a week it looks to be healing at a slower rate than anticipated. It could be up to 4 times slower than on Earth. The crew member won't be doing much during our journey to Mars.

After a month in space the next tests will be conducted. So far, on average, the crew has lost about 1% of their bone density. The easiest ways to fight bone density degradation is by increasing calcium, potassium, magnesium, vitamin D, and protein intakes. The plants that are grown on the ship are modified to grow and survive in space as well as packed full of all the nutrients the body needs to remain healthy.

On Earth there was an experimental procedure to help increase bone density in patients with osteoporosis. I believe it could be applied to help reduce the effects of space travel on our bones. A gene mutation was discovered in a family that had abnormally high bone mass. The mutation in this gene causes the body to make high amounts of a protein called LRP5 (low density lipoprotein receptor-related protein 5). LRP5 influences how much bone is formed and maintained. This experimental drug was supplied to us, however the doctors at NASA have said to only use it when we hit the mid-way point of our journey. If the crew member with the broken arm does not see significant healing in 3 weeks, as Chief Medical Officer, I will pull rank administrate the drug.

Human Bone Density



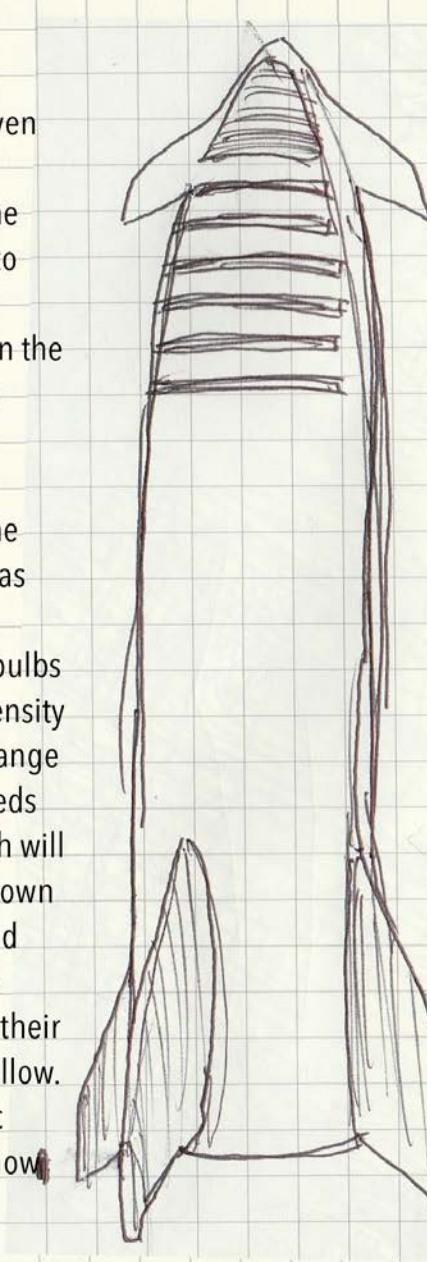


MEDICAL LOG 2025.11.10 DAY 054

The day to day activities of space have proven to be harder than anticipated. In the mornings, I try to wake up between the time that the crew goes to bed and when the rest of the crew wakes up. I knock back a protein bar and get an hour of exercise on the new ARED machines (Advanced Resistive Exercise). The machine uses a platform and hydraulic pressure as weight resistance. The machine can be configured into bench press, curls, military press, squats, pull downs, and many more. Its quite awkward at first but, you get used to it. After my workout, I head back to my cabin and space shower. I do miss my rainfall shower with. I change, and head for breakfast. Breakfast is protein packed powdered eggs and space spinach. I wish we had replicators from Star Trek. I could go for bacon and French toast right about now.

After breakfast are scheduled system checks. I help check all life support systems on the ship, oxygen quality and contamination. The filters in all duct intersections are checked every 2 weeks and filters further down the system are checked every 4 weeks. Air must keep cycling throughout the ship, if there are dead zones where the air is not flowing from supply to return, pockets of carbon dioxide could form causing oxygen starvation to anyone in the area. The air must keep flowing around the ship nonstop. It can get quite loud, but you get used to it.

The water systems are checked daily. We must recycle all our water. The closed-loop system onboard the ship uses chemical and biological treatments, impurities and contaminants in wastewater are removed to turn it into clean drinking water. Wastewater, urine and sweat, even the moisture from our breath is captured, and impurities and contaminants are filtered out. The final product is potable water that can be used to rehydrate food, bathe, or drink. And repeat. The system sounds disgusting, but recycled water on the Heart of Gold is cleaner than what most people consider clean drinking water on Earth.



The greenhouse is located on the level above the water system control centre. The crew refer to it as the "rainbow house". Different plants require different amounts of light and intensities. LED bulbs shine red, green, or blue depending on the intensity needed for the plants. The botanists want to arrange them into a colour wheel. The initial planting beds were randomized to increase germination which will produce a diversified nutrient soil. Plants are grown in plant pillows; the pillows contain fertilizer and seeds. Their roots will grow downwards into the substrate provided by the plant pillow and that their stems will grow upwards outside of the plant pillow. They are working on hydroponic and aquaponic systems for when we get to Mars. I'm not sure how the fish in the aquaponic systems will handle Martian gravity.

At lunch we eat the greens that have been growing on board and surprisingly they aren't bad for space plants, along with the salad, we get mystery packs of protein shakes and other dehydrated meals. I say mystery because they don't resemble food, but they are edible and taste pretty good.

After lunch we get a bit of a break when most the crew chooses to exercise, read, or communicate with loved ones. I ventured into the engineering deck once to see what kind of cool gadgets they might have. I started to talk to an architect that has been designing future settlements. Our habitats will be the simple light weight structures that NASA and MESEA sent in advance with pre-mission supplies and we get to cannibalize one of the drone supply ships which was damaged during space flight. The parts to repair it were too heavy and costly to send with our mission, so it was decided to let it remain on Mars whilst other supply ships were able to return to Earth. The architect on board showed me a book about an architect from the 1970s that went into a coma, wake up in the future, on mars, as a robot sent from Earth. But before he could finish his story, he was called away.

I returned to the medical bay and begin analysing the test results from the crew. After almost two months in space, the crew have grown an average of 2-3 inches. Because we float around the ship, there is no reason why our spines would compress as much as it would on Earth, so our spine stretches whilst in zero gravity. Luckily our space flight suits are made with expandability in mind and the stretch as we do, or we can unzip and instantly get longer arms, or legs with folded material hidden within the suit.

The crew member with the broken arm has not been healing. It has been about 4 weeks since the break and his broken arm is only at the stage of a one-week old break on Earth. Doctors on Earth are interested in seeing x-rays and MRI scans, so I have been given permission to reroute power to operate the heavy amounts of energy needed to run the MRI. Other members of the medical crew have been prepping the machines and working with engineering to coordinate the energy transference. Tomorrow we will begin the scans. Finally, at the end of the day I submit a medical report to the captain.

We finish the day with announcements from the flight crew regarding how the ship is fairing on its journey. The ship has been at 100% health for the entire journey and we hope it remains at that level. The captain then goes over trajectory, fuel, system checks, crew health, life support, and other vital systems that require the ship and crew to remain functional. After the announcements we get to eat our high nutrient meal packs and spend the rest of the evening in free time. I like to wind my day down with an hour and a half run then meet up with other crew members to talk about their days. There is no curfew, but the main lights in the corridors switch to a dim red glow at "midnight". Whatever time midnight is in deep space.

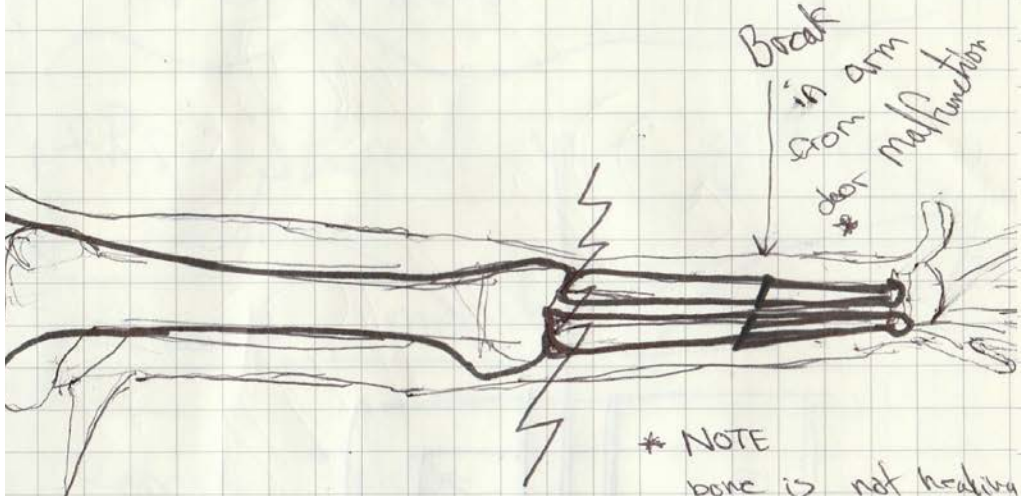
MEDICAL LOG 2025.11.26 DAY 070

NASA finally got back to us about that broken arm. At the rate of bone density decay and the healing speed of the arm, it is advised to amputate the arm and replace it with a 3D printed prosthetic. The prosthetic arm will be fully functional and connected at his elbow, and he will be able to move his fingers and use his hand. After consulting with him, he decided it would be "cool" to get a bionic arm. The printing will take a couple of days to complete and then the procedure will follow.

MEDICAL LOG 2025.11.30 DAY 074

The forearm was printed and tested faster than anticipated. He was sedated, and the forearm amputated, making sure to leave some muscle tissue at the elbow to graft onto the new bionic part.
It was odd to operate in zero gravity. I was strapped to the floor of the sealed chamber, all tools and instruments had magnets and any arrant blood floated around the room bouncing or splattering off the walls in slow motion. It was gruesome.

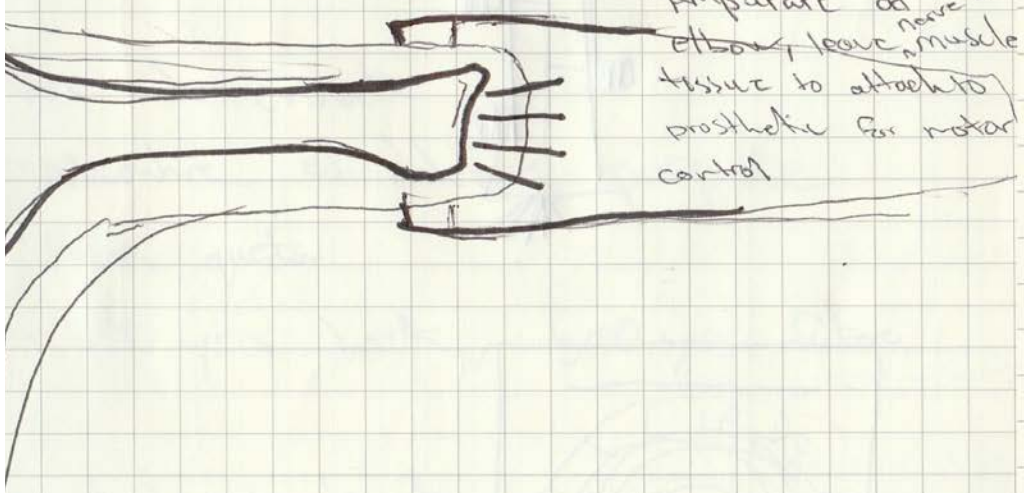
The crew member will stay in sickbay for a couple of days, to be monitored and to test the connection between the new arm and his brain. Early results are promising.

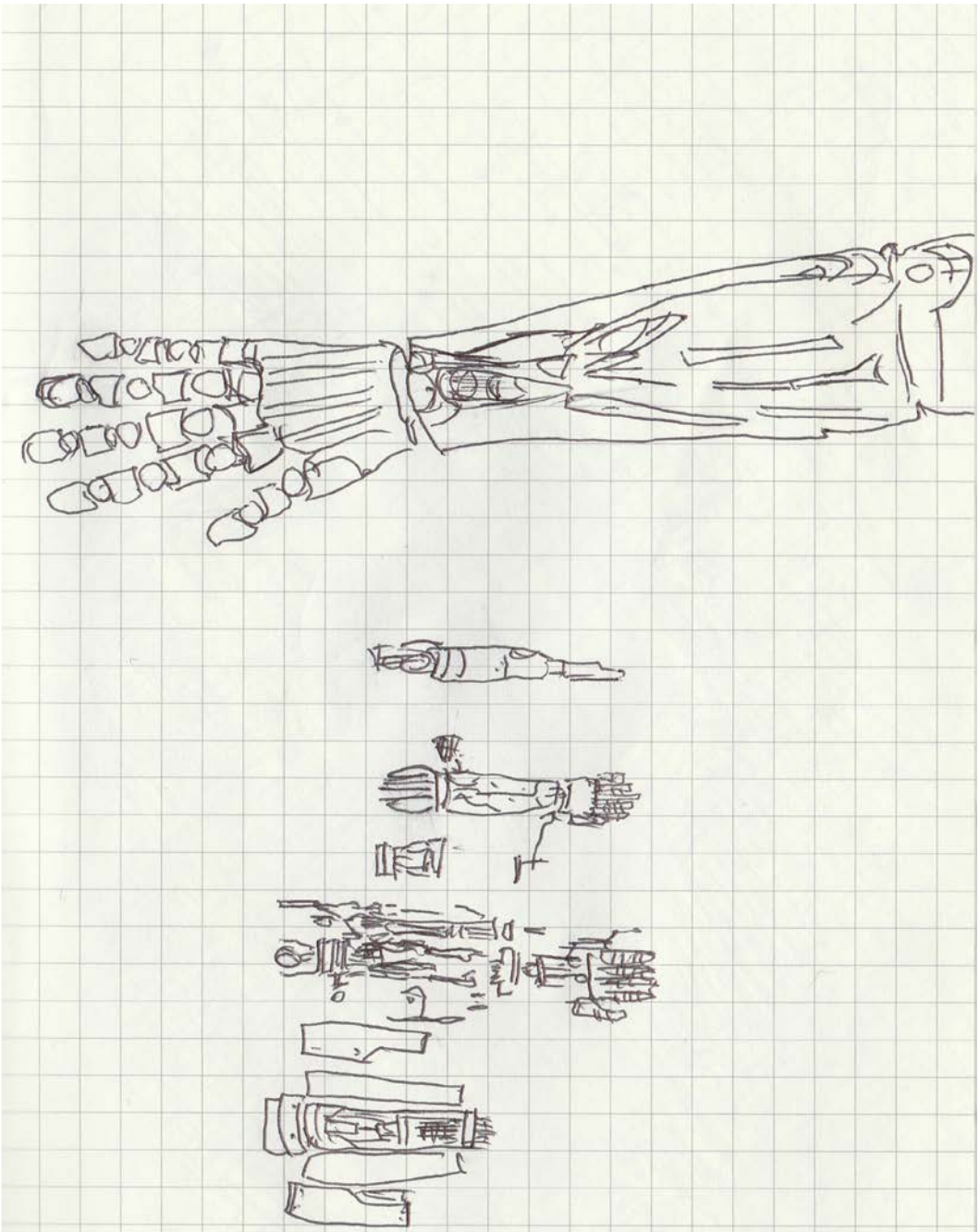


* NOTE
bone is not healing in space flight

· Nasa suggests amputation because arm may ~~be~~ die
· replace with robotic prosthetic to be printed onboard.

· Amputate at elbow, leave nerve endings & muscle tissue to attach to prosthetic for motor control





MEDICAL LOG 2025.12.19 DAY 093

I was able to get the rest of that story from the Architect on board. He showed me the book, it was in rough shape, the book had been around for a while judging from the wear and tear. Written in the 1990s by an architect named Azrieli, about the dreams he experiences in his coma. In his dream, he is a rover on Mars, in the future. His family didn't want to pull the plug because his brain was still showing signs of activity, clearing dreaming, and when he finally woke up 20 years later, the first thing he asked for was for a pen and lots of paper. He began to draw amazing cities on Mars, built by robots for humanity, but humanity never came, and the robots built the cities for themselves and extracted resources to send to Earth. He published it just before the new millennia and it was successful amongst groups of people including futurists, architects, nerds, space enthusiasts, science fiction novelists and many more. He became a professor and taught classes on space architecture and the future of space travel. All his ideas and work were from a dream he had while in a coma. He discusses his adventures on Mars as he traversed the planet looking for sites to build cities. His journey ended once he completed a network of cities across the planet, spanning over almost a century. The massive cities he designed and constructed using drones were connected by highspeed trains that spanned the planet. Starting from the space elevator at Pavonis Mons at the equator, then running across the equator to sites branching out from the spine of the planet to the north and south regions like the limbs of a body.

MEDICAL LOG 2026.01.12 DAY 117

Almost 4 months into the voyage, and the crew's health has all checked out perfect. However, their mental health has not been its best. Many miss their families, including myself, and crew members habits are starting to aggravate each other. The psychologist and I will perform mental evaluations on different crew members to evaluate the tensions between crew members. We recommend a day of rest for the crew to reset and for the captain to say some encouraging word to boost moral.

Space is stressful enough trying to survive, but trying to survive with 99 other humans in close quarters can be difficult, especially if everyone has their own ideas; religiously, politically, ethically, spiritually, culturally, and whatever other way people are influenced.

MEDICAL LOG 2026.01.28. DAY 133

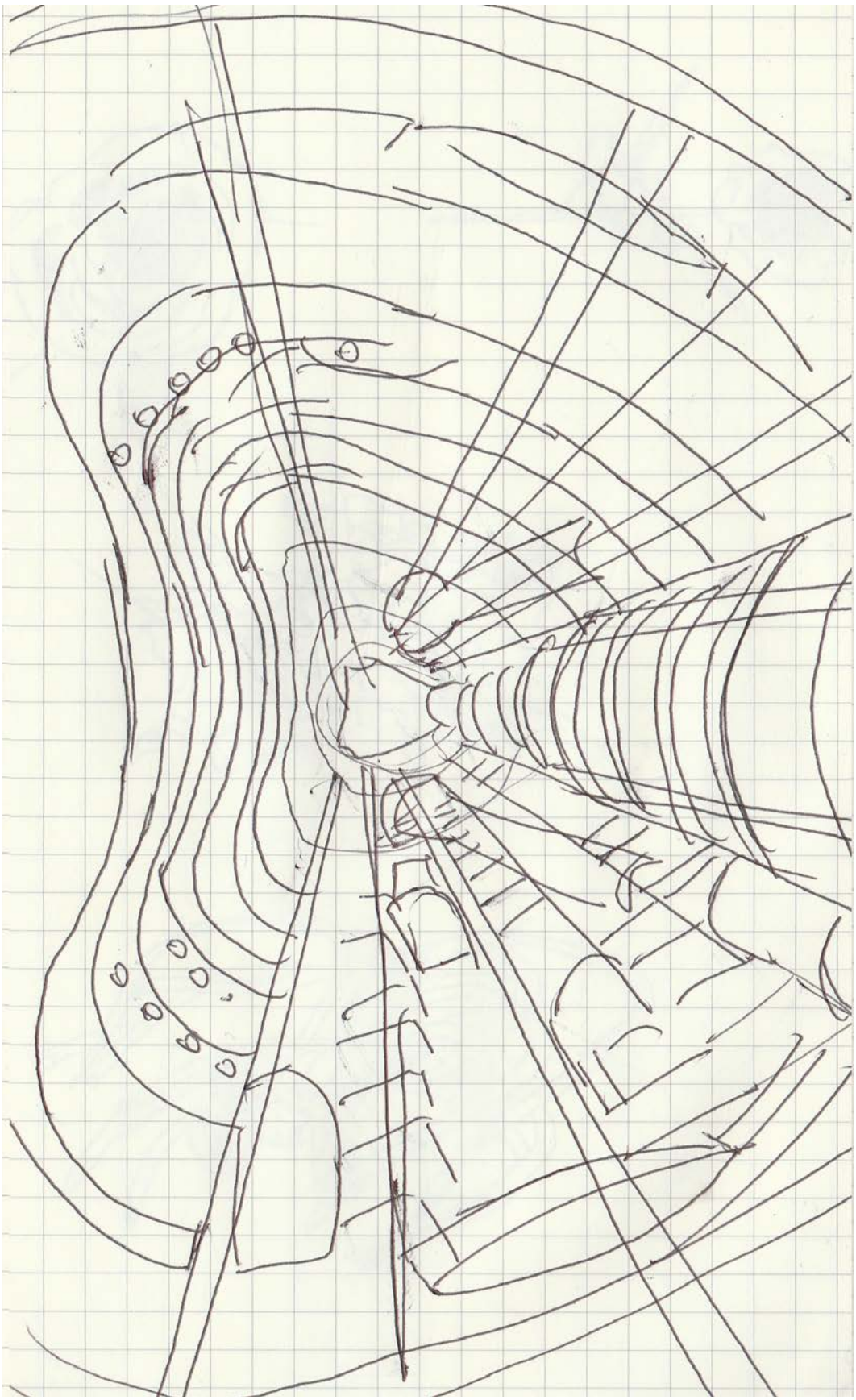
There was a red alert today. The ship was hit by a massive solar flare, which by my understanding, is caused by a coronal mass ejection from the Sun. The flares travel at 1,000km/sec across space and their occurrence is unpredictable. Lucky for us, most space protons in the solar flare are not able to penetrate the hull of the ship.

The shielding on the outer shell of the ship and the new experimental electromagnetic shielding sheltered us from the solar radiation. If it had gotten into the ship, it would have damaged all the systems, which would have led mission failure.

In the centre of the ship is the grand atrium where people can travel the length of the ship. The walls and doors around that room close and are double reinforced in anticipation for such events. We were able to retreat to the safe zone, except for two. We found two engineering manning the consoles for the shielding.

The two crew members are now in the sickbay with massive burns over their bodies. Cosmic rays that hit the two crew members were swept into the ship by the flare. The patients will have to remain in sickbay for the remainder of the journey. The medical team will apply synthetic skin to the burns, because of how deep the wounds are. The burned flesh was stuck to their clothes, making the wounds deep, almost to the muscle. Not a pretty sight, or smell.

We reported the incident to NASA, but we had no reply. Both COMMS and NAV are down, the solar flare damaged the communication equipment on the outside of the ship and repair crew are space walking right now to get them working.

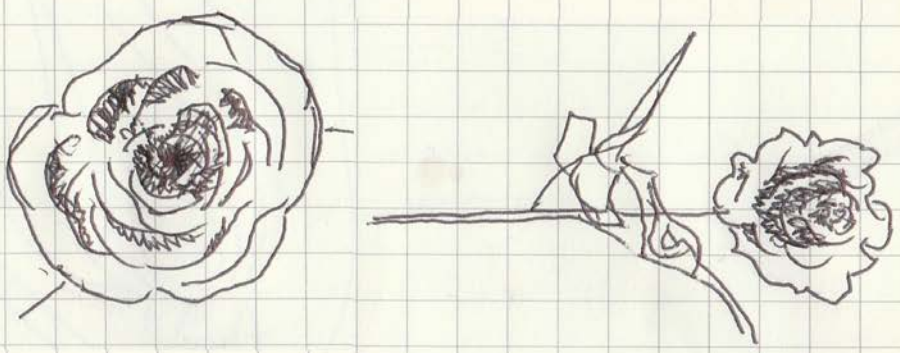


MEDICAL LOG 2026.02.14. DAY 150

The two crew members that were burned 17 days ago are healing. They have been back on their feet, but their range of motion is limited. Lucky for them we were in space and they could float everywhere. The synthetic skin works by applying a layer of stem cells onto the wounds then covering the wounds with the "skin". The skin then acts as a scaffold and protector for tissue to regenerate. The "skin" is applied by cross laminating strips of thin layered synthetic skin, like applying papier-mâché. The other crew members are calling them heroes for saving the rest of the crew. NASA and MESEA have given them medals for bravery, which engineering 3D printed.

With all the testing, daily activities, and sick crew members coming into sickbay; myself and most crew had forgotten it was valentine's day. The captain made the announcements over dinner and surprised everyone with roses the gardeners and botanists grew in the VEGGIE greenhouses. It made the ship more colourful than the sterile surgery room white.

The lighting system on the ship is programmable. The ceiling of the atrium was programed to mimic sunlight and blue-sky, but when we were hit by the flare, the auxiliary systems were reset, and we lost the programming. The engineers have been having trouble restoring the system. They believe it is because of damaged relays. There are over a million kilometres of wires across the ship so finding it is like finding a needle in a hay stack.

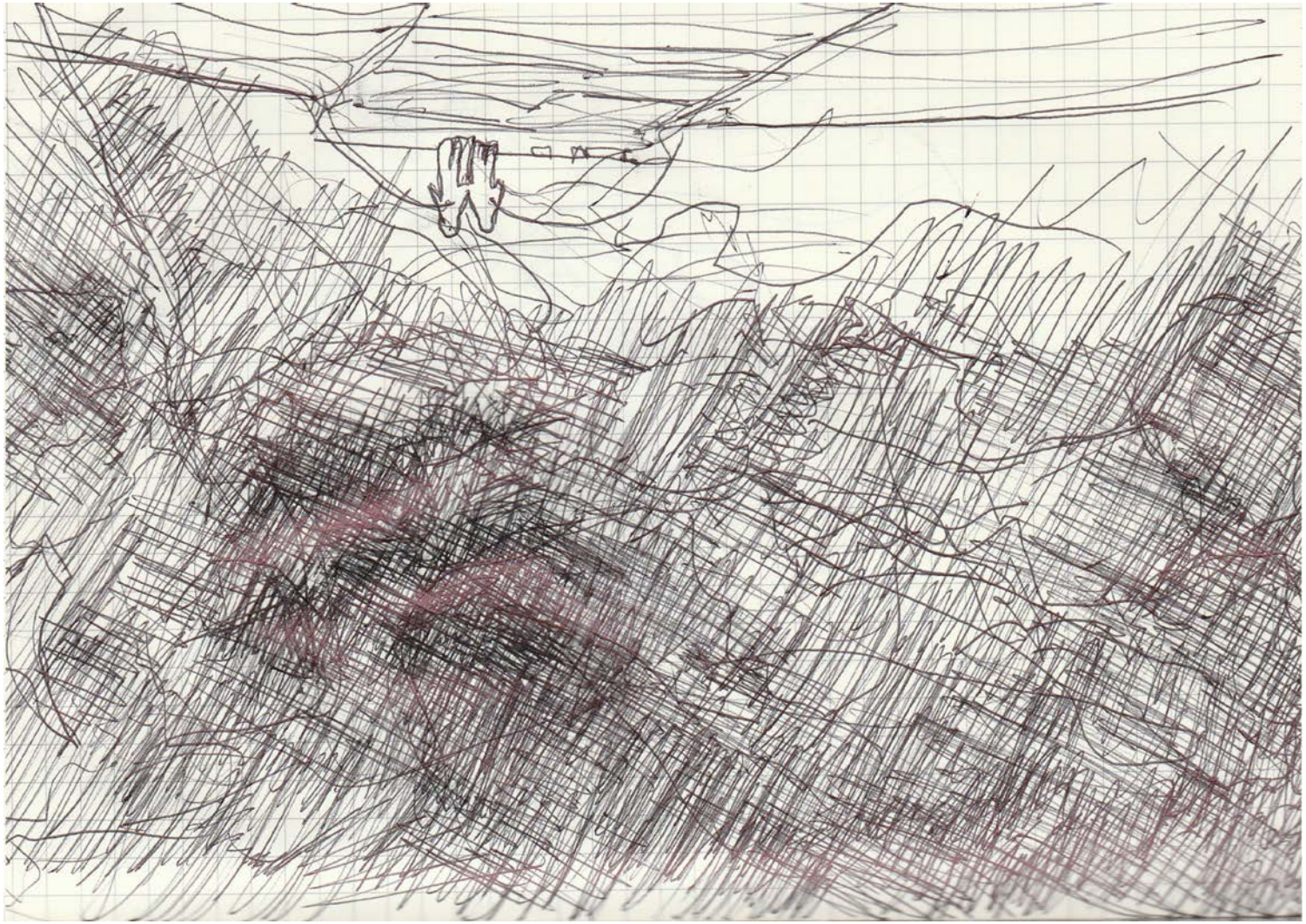


MEDICAL LOG 2026.02.16. DAY 152

The captain, under instructions from the crew psychologist, has given me the day off. Says I have been working too hard. Just over 5 months into the journey and I feel burned out. Much of the crew has been given time off. I completed a cycle of crew testing and reports, so it will be a nice break. They have given me 2 days of free time. There isn't much to do, but I'm determined to make the most of it.

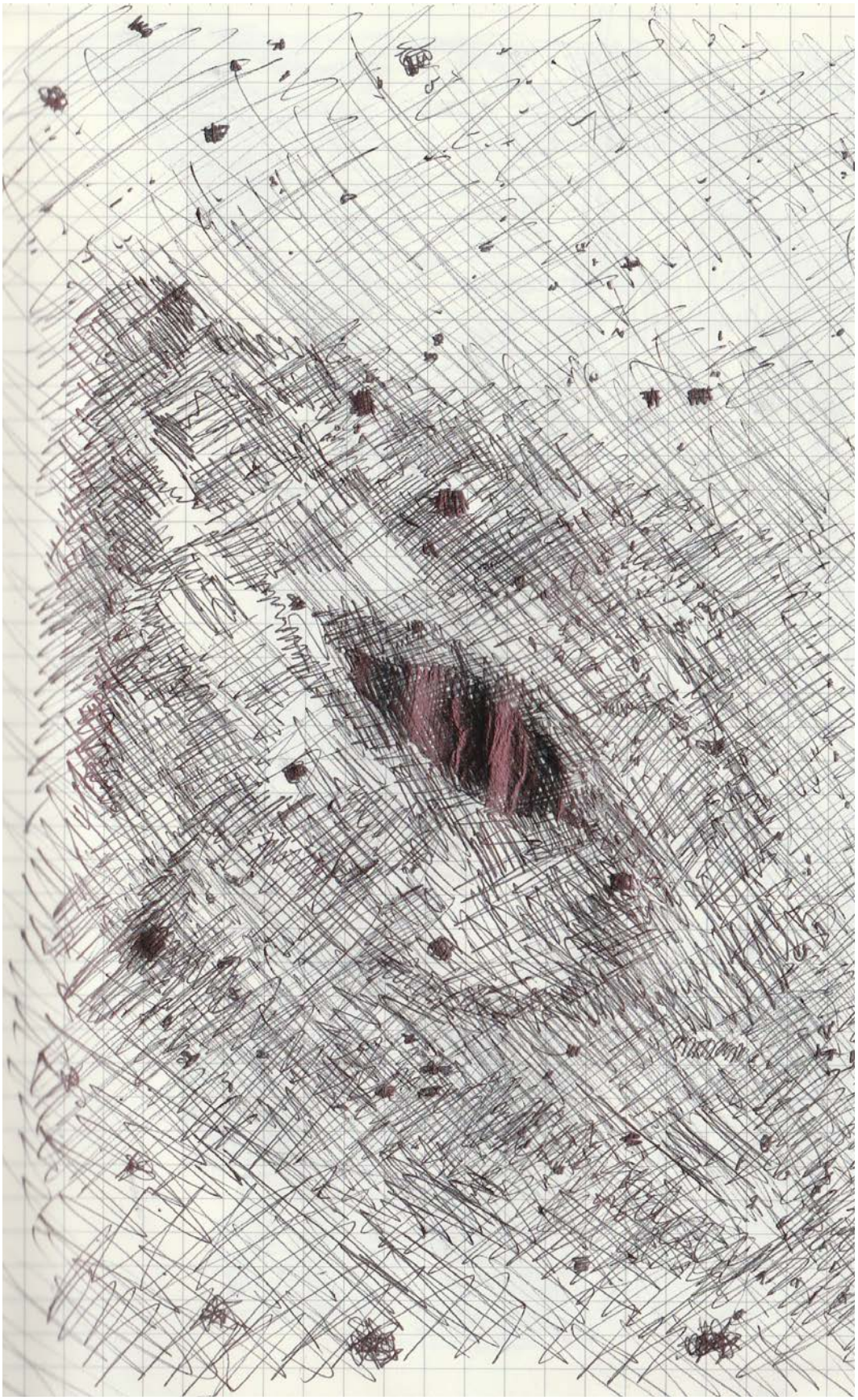
PERSONAL LOG 2026.02.17. DAY 153

I went on a space walk today, it was amazing! I strapped on my spacesuit and climbed onto the outer hull of the ship, tethered myself and turned the magnetic boots off and let myself float. The closest object is millions of kilometres away and the thing we are travelling in, a tiny metal tube, is travelling at over 20,000km/h, towards a planet that may, or may not be able to support us. We see ourselves as a strong and intellectual species, yet we kill ourselves, fighting over made up things like religion, man made borders, and we pollute our planet. Humanity thinks we are so smart, but here in the Heart of Gold, protected by the latest, most advanced technology humanity has at its hands, we still can't, or should not survive, we are so insignificant in the universe.



MEDICAL LOG 2026.02.27. DAY 163

Its been quiet the past week. Our captain pointed out that we will be getting our first glimpse of Mars today. Naturally everyone jumped to the front of the ship to get a peak out the massive dome at the front. It is more of a bubble at the front of the ship that has retractable heat shielding when lifting off and re-entry but serves as an observation deck during space travel. I like to go there late at night if I can't sleep and stare into the stars. There is a powerful telescope in there. Once I was able to get an exposure long enough to see Andromeda.



MEDICAL LOG 2026.03.03. DAY 167

The medical implants have been transmitting medical reports of the crew members to sick bay throughout the journey and I have noticed that certain members have shown increases in cell degradation and DNA mutation. I have been investigating the causes of the higher than normal radiation, but I can't locate the source. I will continue my investigation with the water and air system tomorrow. The Carbon dioxide scrubbers are working and filters have been changed twice as frequently.

MEDICAL LOG 2026.03.06. DAY 170

After days of looking into the occurrence of the crew's health problems, I discovered that the crew experiencing issues have cabins in the same area of the ship. Something is happening in that area of the ship; leaking radiation maybe? But the reactor room is nowhere near the living quarters, plus its shielded more than the outside of the hull. A couple of days after liftoff we heard a large bang outside the ship. Maybe its something outside? But it was checked and cleared. I think another look outside should be worth it, this time with equipment to see if anything is leaking out, or into the ship.

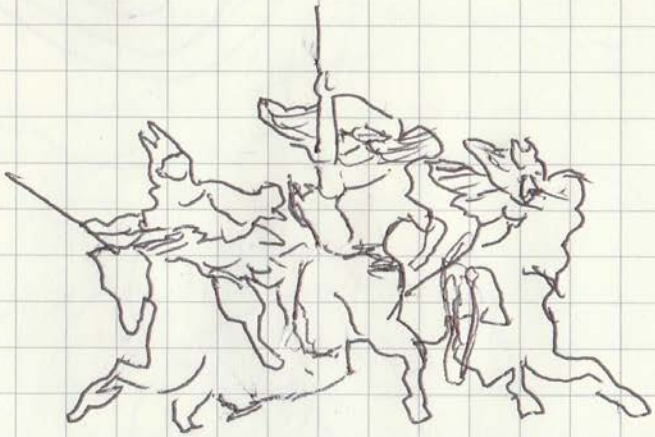
MEDICAL LOG 2026.03.08. DAY 172

My assumption was correct. The captain sent a maintenance crew on a space walk of the ship and they discovered that a small crack formed on the outside of the shielding tiles. Nothing penetrated the ship's hull, but it was big enough that the tear in the shielding would allow cosmic rays to enter the ship.

They managed to repair the break by replacing a section of the shielding and I began treating the extremely sick crew members first. By synthesizing their blood from their original samples, a treatment can be developed to promote the development of healthy white and red blood cells to fight the mutated cells. Combined with nanotechnology to target cancerous cells within the body, the astronauts should be healthy by the time we arrive at Mars. This technology is only experimental but has been promising.

MEDICAL LOG 2026.03.28. DAY 192

As we approach Mars, it is getting bigger and bigger in our windows. It's about the size the moon would appear if I was looking at it from the surface of earth. Oh, how I miss the moon. Being of Norse descent, I loved the night sky and the legends that went with it. Being able to see the stars and the aurora borealis in the night sky as a child, my father would tell me about the Valkyrie leading warriors into battle. The aurora borealis is the Bridge of the Gods, name the Bivröst, the bridge that would glow and pulsate, a Rainbow Bridge, leading those who had fallen in battle to their final resting place in Valhalla. This Starship, the Heart of Gold is our Bivröst, leading up to the heavens, crossing over the vast ocean of space to Mars, where we will continue humanity, up in the heavens.



MEDICAL LOG 2026.04.20. DAY 215

We are four days away from being the first settlers on Mars. Final preparations for landing are underway. System checks, crew checks, final calculations for trajectory, re-entry, flight and landing started. The deceleration process started last week to gradually slow the ship down so don't over shoot the planet. Medical reports have been completed and everyone is reading as "normal", whatever "normal" is for having travelled this far into a space.

As we have travelled an inventory of our supplies have been kept and apparently, we are over weight. Our rations have last longer than anticipated and the captain announced we will have a large feast before we land to commemorate the journey. NASA suggests we don't do that, but what are they going to do about it? Communications take at least 20 minutes to transmit from Earth to Mars.

I noticed that in the past month, morale has increased to the same levels to when we started our mission, the 3/4s effect. The crew are working together more efficiently and seem to be energized. Our psychologist says it is because the end of the voyage has arrived, but I only see it as a small milestone in the long voyage. Getting to Mars was easy, the hard part will be establishing a settlement and preparing for the next batch of settlers. We have studied Mars, but we don't fully understand it. There will be much more to learn once we touch the ground.

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MEDICAL LOG 2026.04.25. DAY 220 Sol 1

We made it. Mostly in one piece. Martian gravity is strange, it'll take time to get used to it. The crew will have space legs for a couple days. I need to get the on-planet sickbay/hospital functional. A prototype moveable medical centre was launched pre-mission in the drone ship that was damaged. I will need to find it and bring it out of the ship. The captain has given me a team to assist in getting the medical centre up and running. But communications are top priority.
The crew agreed that we will adopt a 24hr day to remain consistent. We have been doing that since we left the Earth and we will continue to do so on Mars, even though a Martian day has 24 hours and 39 minutes in a day. The last 39 minutes of the day will be like a limbo time. The clocks will stop and after 39 minutes, the clock will hit 12:01am. The captain got the idea from Kim Stanley Robinson's Mars trilogy. They were also a crew of a hundred top scientists and engineers from earth, though mostly from the US and Russia. Our crew is more diversely representative of the entire Earth.

MEDICAL LOG 2026.06.18. SOL 54

The first settlement has been established. A camp of temporary shelters centred around the Heart of Gold, which has become the main power source because of its nuclear reactors. This is only temporary until solar and wind farms have been erected and are working at 75% capacity. Then the power reserves of the Heart of Gold will be used as back up emergency power supply only.

MEDICAL LOG 2026.07.14. Sol 80

Everyone has been ok medically, both physically and psychologically. Everyone seems to be communicating well enough and no tensions have risen.

MEDICAL LOG 2026.09.17. Sol 145

It has been a year since we left the Earth, 7 months in space flight and almost 5 months on Mars. Life on Mars has been good. The settlement is operational. I have been monitoring the crew's health since we arrived and most seem happy and healthy. Radiations levels are increasing though and some are complaining of rashes and burns.

I examined some and the most common result is rashes, burns and blistering on the skin. I have done all I can, but the amount of cosmic radiation we have been exposed to is slowly killing us.
I found that many of the crew are complaining of vision problems. I guess 1/3rd earth's gravity is enough that fluid would still float around. Unfortunately, there is nothing that can be done, fluid will always float.

MEDICAL LOG 2026.10.23. Sol 182

We lost our first crew member today. It was one of the crew that was sick on the Heart of Gold during our journey. The other crew members that had the same conditions as she during the space flight have been in the medical centre for the past couple of weeks, all showing similar signs. The treatment that we administrated on the ship failed. It seems as we strain our bodies on the planet, we are doing more work and our blood isn't receiving enough fresh oxygen for the blood cells to regenerate. The mutations were never stopped, just maintained to a point where they were not affecting the body. But now, the mutations in the cells and DNA are fighting back and we no longer have the ship to protect us.
The underground settlement needs to be completed soon, or I fear we are all going to end up like the sick crew members.

MEDICAL LOG 2026.12.01. Sol 221

We lost 2 more members of the crew. One was the crew member that had his arm amputated and the member of the crew had damaged their space suit. I don't need to tell you what happens when the suit is damaged - It was not a pretty sight.
The captain has been taking the deaths
heavier than anticipated. She feels responsible. The psychologist and I told her not to worry. There was nothing that she could do, this is space, things happen and if you mess up there is no second chance. Everyone on this mission knew the dangers, they came on their own free will.

I noticed that I have started to develop rashes on my legs. I have been dosing myself with some experimental treatments that I have been developing but are considered unsafe for human trial. I figured I would be the best test subject. This is batch 75.5, it worked for a month, but it has failed recently.

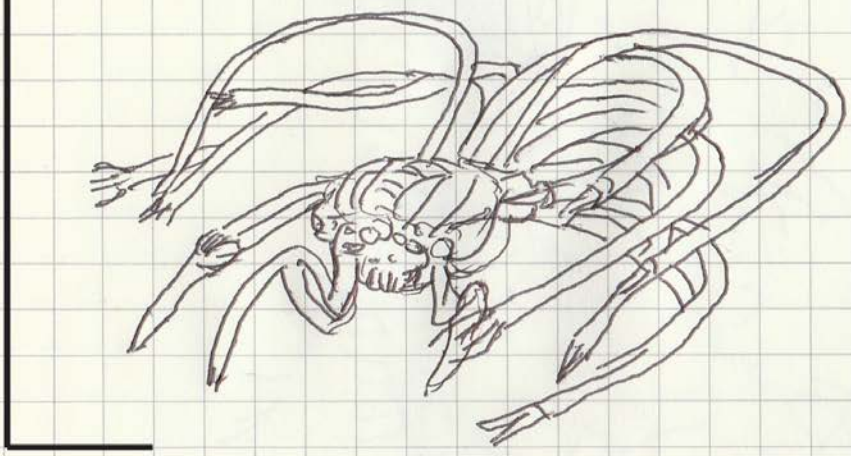
MEDICAL LOG 2027.02.18. Sol 300

Our new underground home was competed last month, and I have been finishing the medical centre since. My newest batch of anti-mutation synthesised blood has been successful and been administrated to the crew. I took time because I had to use each of the crew's blood separately to sequence the DNA and edit the mutation within the blood. Also manufacturing enough nanotech to help the treatment has taken a lot of time. Luckily the 3D printers can print at the microscopic level and do complex prints for circuitry and other tiny electrical components.

MEDICAL LOG 2027.04.15. Sol 356

Almost one Earth year on Mars has passed and we have lost 10 crew members. Morale is low, there are talks about scrapping the mission and returning home. NASA and MESEA are debating whether they should be sending rovers back to Mars to begin settling the planet because the human body simply isn't made for such a grueling journey. Apparently, there has been a breakthrough in artificial intelligence and robots are able to adapt to situations and conditions faster than before.

5µm



MEDICAL LOG 2027.05.09. Sol 380

It was voted unanimously by the UN to scrap our mission. Deaths have been far greater than anticipated, and our health continued to decline. Some of the crew refuse to return to the ship, they want to stay on Mars to continue the mission. The group of scientists that wish to stay are looking at the long-term end game; rehoming the billions of lives on Earth when the Earth can no longer sustain humanity, and we have nowhere to go. If we sacrifice ourselves now, billions of people will survive.

The captain argued that they can still help the people of the Earth, from Earth. By developing technology on Earth, we can accelerate development times on certain aspects of a Mars mission because we now know all the unforeseen problems. By sending robots to Mars, how are unaffected by space travel, Martian gravity and radiation, we will be able to build settlements before we even arrive. The infrastructure will be ready for us. The Captain added "they would do better work from the safety of Earth, than they would be able to do on Mars." She did leave out the part where I have authority to knock any crew members out if they fail to follow command. Only the Captain and I know about the emergency protocol. The "Emergency Medical Protocol", allows me to immobilize a member of the crew in case of mental stress.

The Heart of Gold has been reassembled and it is ready to return home. NASA requested that we bring back samples of Martian rocks. We were able to get enough fuel from the BFR Fuel Propellant Factory that extracted the methane from the atmosphere and the planet. We launch tomorrow at 12:00:00 UTC. Our medical, food and other supplies are low, fortunately for us, on the way to Mars right now is a resupply ship that NASA sent months before our abort order. We plan to rendezvous with the supply ship and transfer over supplies for the remainder of our journey. The resupply ship is a couple of weeks out from Mars, so we won't have to worry about running low or rationing our supplies for our journey back.

MEDICAL LOG 2027.05.29. Sol 400

Sol 400, we didn't even make it one full Martian year. It is my birthday though. So, happy birthday to me.

Even after the Captains speech about continuing research on Earth and making it home to live longer, there were still a few crew members too stubborn to listen. So, I activated the emergency medical protocol in their implants. This released a sedative that knocked them out, then we strapped them in for take off.

MEDICAL LOG 2028.01.01. DAY 218

We arrived back on Earth yesterday. Being back on Earth after 2 years, 3 months, and 16 days doesn't seem like a long time. But a lot has changed. The Toronto Maple Leafs won the Stanley Cup, something I never thought they would do, my sister got married and had triplets (all named after Norse gods), robots are everywhere, the US government and banking system collapsed under the now deceased president and my local bar closed. That's a lot to learn in less than 24 hours after landing from a long-term space mission.

With the lack of crew on the journey back, I had forgotten to write log entries, NASA won't be happy about that. Oh well, we are back now with no injured, sick or dead.

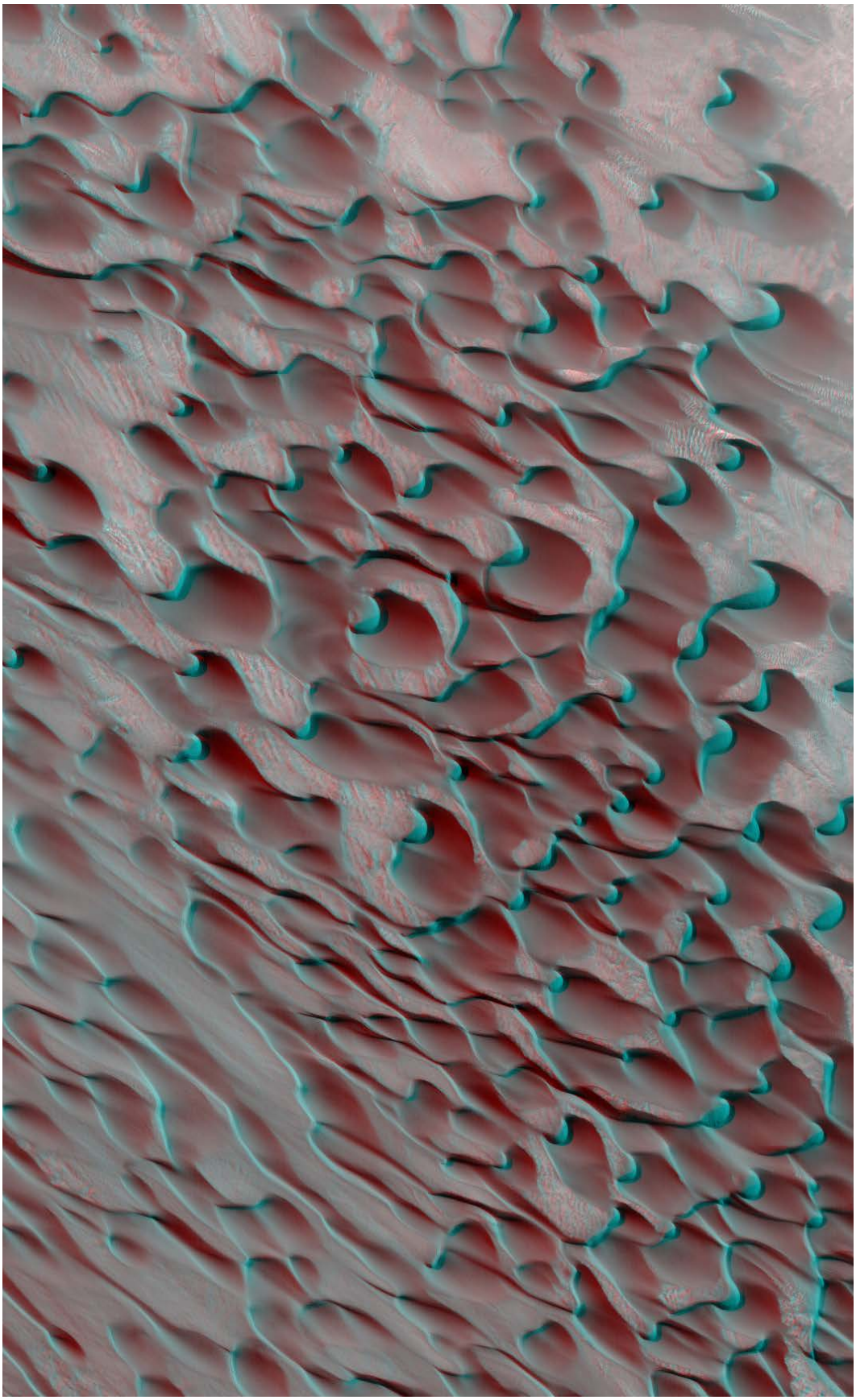
After being in space for so long, NASA and MESEA want to conduct tests on us to see how our bodies changed. As Chief Medical Officer, I will continue to be conducting most of the experiments and testing myself with a team of medical experts.

PERSONAL LOG 2028.01.01. DAY 001

ıave realised that we were never meant to leave the Earth, not right ɔw anyways. If we were meant to leave, we would have evolved to do In time, we will have developed significant technology allowing us traverse the emptiness of space and survive without the hardship ı our fragile bodies. Until then, I'm happy to be home. It's the ɜginning of a new chapter in my life and marked perfectly with the art of a new year.

The Future

NASA and MESEA would not send another human to Mars for 50 years. Armies of robots and drones were deployed to begin settling the planet, awaiting humanity to follow. By the time technology had been advanced enough, cities had been built and the infrastructure already setup to continue human advancement on Mars and further into the universe.

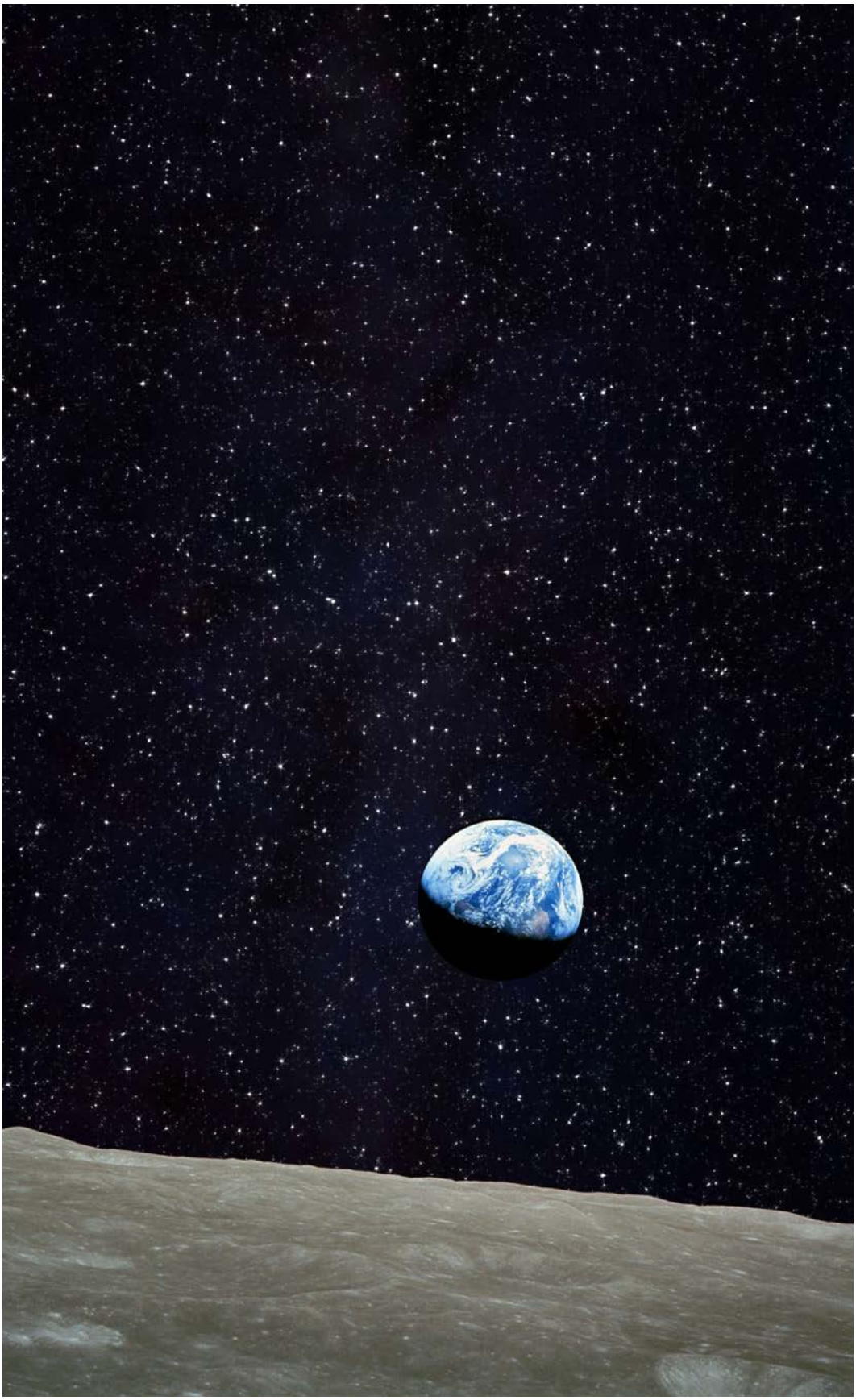


[North Polar Terrain. HiRISE/ NASA/JPL/University of Arizona]

03

EARTH, THE BLUE PLANET

Earth, Our Home



[FIGURE 2 \\\\ Earth rising. Apollo 8, the first manned mission to the moon, entered lunar orbit on Dec. 24, 1968.
Astronauts: Commander Frank Borman, Command Module Pilot Jim Lovell, and Lunar Module Pilot William Anders. NASA. 1968]

EARTH, OUR HOME

\\\\ EARTH, THE BLUE PLANET

Earth, as described by the "**Hitchhiker's Guide to the Galaxy"**, is "Mostly harmless".[5] The Earth has been our (homo sapiens) home for about 200,000 years and will be for as long as we can survive on the planet. Over the history of the Earth there have been five major extinction cycles in which 90% of all life vanished.[6] Organisms faced with hostile environments come to one of three fates; they leave the environment, they adapted to it, or they died. If we speculate about the future, there will come an event that we as a species will not be able to adapt fast enough; we will have to leave the Earth, or we will perish. In the short term, we face threats that are not natural to the planet, but are largely self-inflicted, like; climate change, nuclear war, weaponized microbes, and over population that is far exceeding the carrying capacity of the Earth. We might find ourselves in an ecological armageddon, fighting for the planet's last resources. Unlike other life-forms on Earth, humanity is the master of its own fate. We as a species can create tools that defy the odds that nature gave us, so we do not become the 99% of all life-forms destined for extinction.

Global warming is the result of the "greenhouse effect" – the atmosphere traps heat radiating out into space.[7] Industrialization and the burning of fossil fuels like coal and oil increased the concentration of atmospheric greenhouse gases, increasing global temperatures. The clearing of land for agriculture, industry, and other human activities has increased concentrations of greenhouse gases. As global warming worsens, temperatures continue to rise, precipitation patterns change and increase, more drought and heat waves, hurricanes will become stronger and more frequent; as polar ice caps and glaciers melt, sea levels and flooding increases. Coupled with the human population increasing at exponential rates, these events are harmful to human existence if we survive. We must consider the possibility that humanity will be in dire need to inhabit Mars.

“

I BELIEVE THAT THE LONG-TERM FUTURE OF THE HUMAN RACE MUST BE IN SPACE. IT WILL BE DIFFICULT ENOUGH TO AVOID DISASTER ON PLANET EARTH IN THE NEXT HUNDRED YEARS, LET ALONE THE NEXT THOUSAND, OR MILLION. HUMANITY SHOULDN’T HAVE ALL ITS EGGS IN ONE BASKET, OR ON ONE PLANET. LET’S HOPE WE CAN AVOID DROPPING THE BASKET UNTIL WE HAVE SPREAD THE LOAD.

// Stephen Hawking, 2010

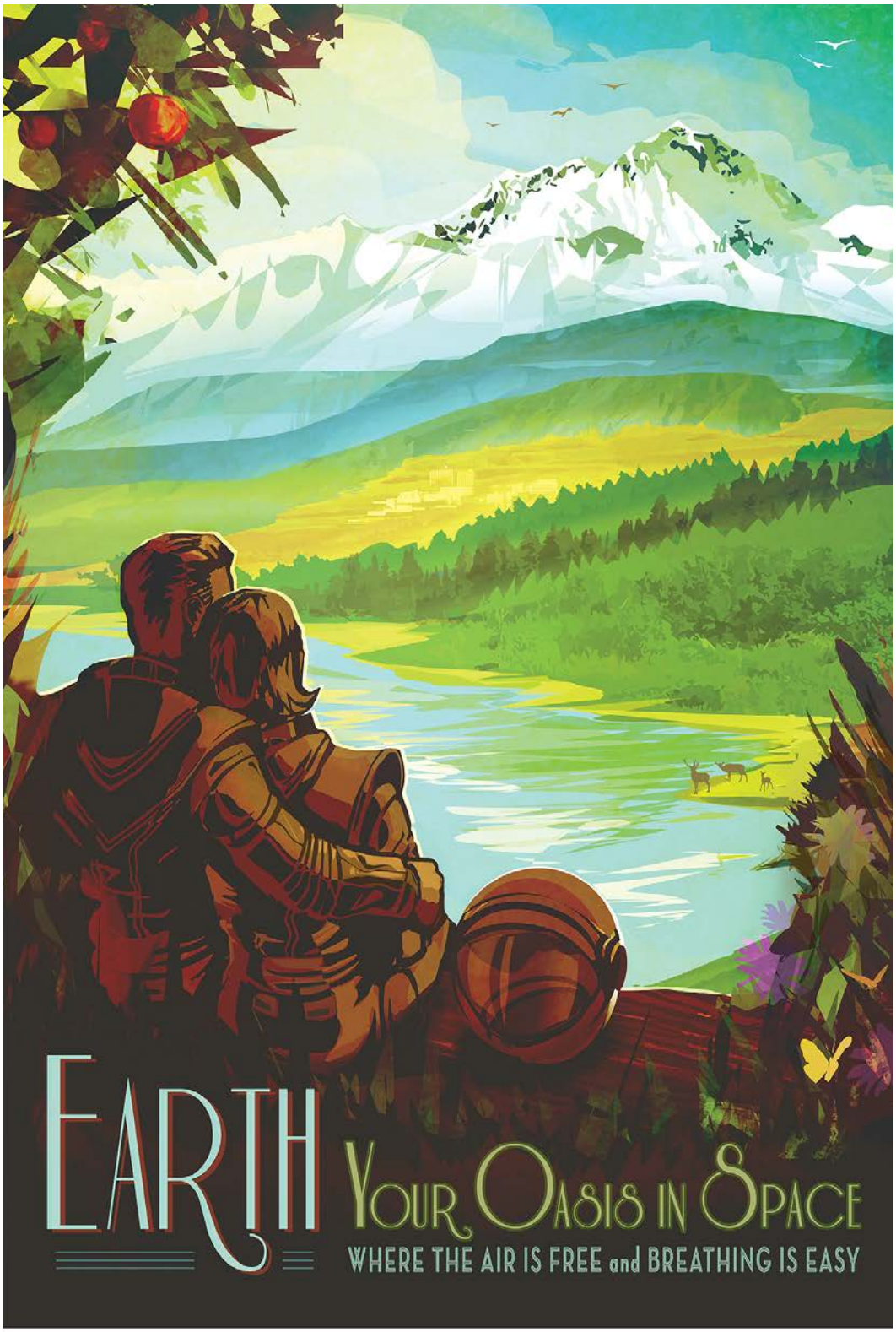
”

Michio Kacku, theoretical physicist, futurist, and popularizer of science, wrote several books explaining heavy concepts in ways that the reader will understand, whilst connecting and speculating concepts of varying topics as they would evolve over time. In "The Physics of the Future: How Science will shape human destiny and our daily lives by the year 2100", Kaku interviews 300 scientists, working in their labs on prototypes (2011) that regulate fast, safe, and advanced technologies. He talks about the effects of global warming becoming prominent by the mid 21st century. In the last century alone, the Earth heated up by 17^0 C on average. The evidence that the Earth is in trouble surrounds us, from ice sheets thinning and breaking off in the Arctic and Antarctica, miles of ice is breaking off the continent and thereby increasing sea levels, to local weather patterns that affect us in our daily lives. Ice in the arctic regions decreased in thickness by 50% in the last 50 years. Polar ice caps may vanish permanently by the end of the century, which would disrupt weather patterns around the world, caused alterations in the flow of ocean and air currents.[8]

For every vertical foot that the ocean rises, the horizontal spread of the ocean is 100 feet. According to the United Nations, the oceans could rise by 23 inches by 2100. However, researchers at Colorado's Institute of Arctic and Alpine Research say that the UN reports are too cautions with the data and oceans could rise by 3 to 6 feet. This would result in catastrophic results to shorelines and coastal cities.

In an interview, Kaku says that "We shouldn't use this as an excuse to pollute the Earth, or let global warming run amok. We should cure these problems without having to leave for Mars, or another planet, because it's impossible to remove the entire population to Mars. We're talking about an insurance policy—a backup plan in case something does happen to the Earth. I once talked to Carl Sagan about this, who said, "We live in the middle of a shooting gallery with thousands of asteroids in our path that we haven't even discovered yet. So, let's be at least a two-planet species, as a backup plan." [9]

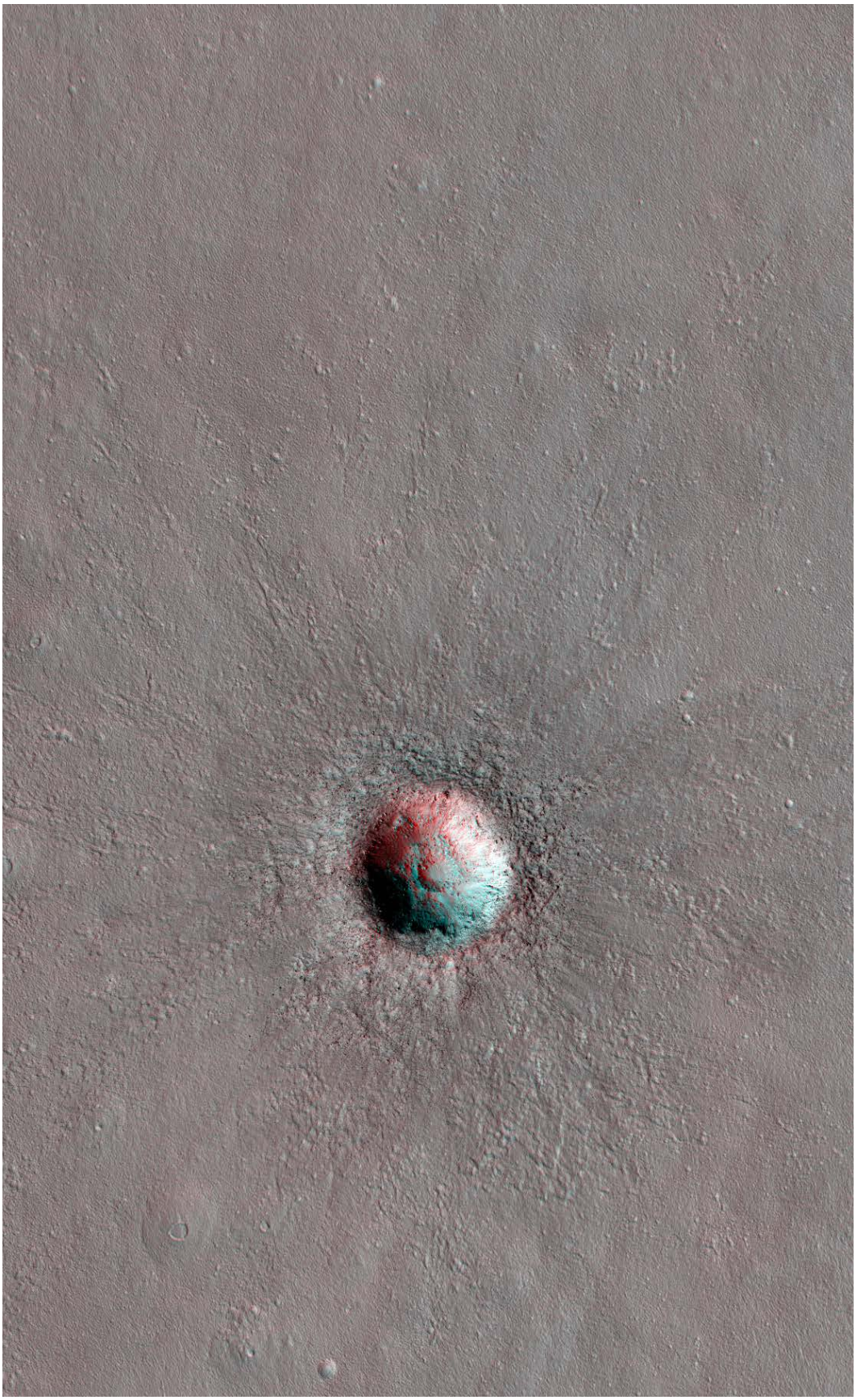
In **"Journey of a Robotic Architect"**, the sci-fi narrative that prefaces this thesis, climate change is halted and reduced to levels before the 20th century. By proposing this altered reality, we as a humanity do not simply rely on leaving the Earth in a disastrous state for future generations. We begin to help the planet heal, allowing humanity to remain on our home, and expand to Mars. The governments of the world are taken over by scientists in peaceful revolutions. There was an increase in the dependency of renewable energy which brought in a type of "industrial revolution renaissance". This plot point was added to stress that Mars will not be the next exploited planet for humanity. Earth will still need to be habitable for humanity to thrive amongst the stars. Mars will be a tool to relieve the demand of Earth's resources.



There's no place like home. Warm, wet and with an atmosphere that's just right, Earth is the only place we know of with life – and lots of it. JPL's Earth science missions monitor our home planet and how it's changing so it can continue to provide a safe haven as we reach deeper into the cosmos.

NASA Jet Propulsion Laboratory
www.jpl.nasa.gov

[FIGURE 3 \\\\ Earth, Your Oasis in Space. JPL Visions of the Future Posters. NASA/JPL-Caltech. 2018]



[Small Crater in Arcadia Planitia. HiRISE/ NASA/JPL/University of Arizona]

04

TOWARDS A MULTIPLANETARY SPECIES

BECOMING A MULTIPLANETARY SPECIES.

"The dinosaurs became extinct because they didn't have a space program.
And if we become extinct because we don't have a space program,
it'll serve us right!"

- Larry Niven

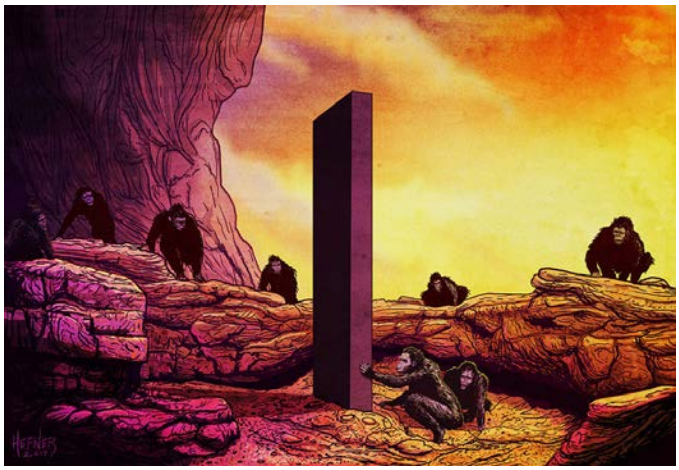
Another magnificent work of science fiction is Isaac Asimov's Foundation trilogy. First appearing in an age where science fiction was a cross between space and the wild west with ray gun battles and space wars. Asimov paints the picture of humanity spreading across our galaxy, 50,000 years into the future, with millions of settled planets held together by a Galactic Empire. With a vast timeline, the origins of humanity are blurred and lost in prehistory. Maybe humanity is destined to expand out amongst the stars, creating civilizations that span to the furthest reaches of Milky Way galaxy and into the next Galaxy far enough into the future. "Journey of a robotic architect" marks the beginning stages of a galactic empire.

Experts agree that humanity needs to become a multi-planetary species within the next 100 years to survive. The planet cannot support life indefinitely, especially when many resist sustainability. Humanity has already taken the first steps to becoming multiplanetary by sending probes into the far reaches of space, the next step would be sending humans to walk on new worlds, Mars should be our first step.

Science fiction authors have written many stories about travelling to other worlds since the early 19th century. Imagine living on another planet, millions of miles from the Earth; looking up into the sky with the knowledge that one of the stars in the sky is the planet you were born on. Those who observed Neil Armstrong land on the Moon still remember every detail – where they were, who they were with and how they felt. The moment the first astronauts land on Mars will be a moment to remember.

Curiosity and advancements in technology have been the driving force of the evolution in humanity. In **"2001: A Space Odyssey"** the prehistoric hominids discovered the use of bones as a way of defending themselves or attacking others. When the alien Monolith is shown on screen, an advancement in technology occurs. The early man uses his new tool to hunt, giving them meat. They begin to walk around upright, becoming modern humans. It is our development of tools and technology that led humanity to evolve. The bone club eventually led to other inventions such as the tools of agriculture, hunting, travel and architecture. This development allowed us to conquer our planet, and ultimately its undoing, and eventually lead to new inventions to tame other planets. Our curiosity of the universe and its contents including our own existence have puzzled humans for centuries.

[FIGURE 4 \\\\ Stanley Kubrick's 2001: A Space Odyssey movie poster. MGM, 1968]



[FIGURE 5 \\\\ Humanoids discovering the monolith. The monolith is said to signify an advancement technology. 2001: A Space Odyssey. MGM, 1968]

By exploring another planet, we can study it and ask if it can teach us about our planet's history? Was/is there life on Mars?

Mars is the next frontier for human exploration. Manned missions to Mars will jumpstart massive developments in all areas of life; recycling, solar energy, food production and the advancement of medical technology, which will lead to better living for humanity on Earth.

By settling on Mars and exploring the furthest reaches of the universe, we ensure the survival of our species. The universe is a complex system that demands complexity for survival. Physicist Sean B. Carroll's "The Big Picture: On the Origins of Life, Meaning, and the Universe Itself" explains that entropy is one of the fundamental components of the universe, and works as an engine that drives complexity.[10] Physicist Sharon Glotzer, who has been exploring the concept of emergence (how and why complex systems emerge from simpler systems) explains entropy:

"We typically think entropy means disorder, and so a disordered structure would have more entropy than an ordered structure. That can be true under certain circumstances, but it's not always true, and in these cases, it's not. I prefer to think of entropy as related to options: The more options a system of particles must arrange itself, the higher the entropy. In certain circumstances, it's possible for a system to have more options – more possible arrangements – of its building blocks if the system is ordered." [11]

Glotzer explains that entropy sets particles to "wiggling," having a tendency to want to maximize their individual "wiggle room". This can drive them into a structure that winds up being complex, when seen as a complete system.

Humanity must wiggle its way to Mars in order to remain complex and survive in the universe. If only complex beings can survive in the universe, then the Earth is like a treasure chest. If humanity continues, our species will give rise to diverse untold wonders of human and post-human life and technology. If we can continue thriving as a species, it may result in intergalactic civilizations of intelligent beings.

However, we are in constant danger, mostly from our own technology, killing ourselves for mundane reasons that don't matter in the greater picture. With nuclear warheads capable of causing an existential catastrophe, or our being confined to this single planet means that a single asteroid collision, or some other unforeseen cataclysmic event could wipe out our entire species and all intelligent life on Earth. "Existential risk – One where an adverse outcome would either annihilate Earth-originating intelligent life or permanently and drastically curtail its potential. An existential risk is one where humankind is in peril. Existential disasters have major adverse consequences for the course of human civilization for all time to come."[12] By travelling to Mars, we increase our chances of survival.

[Wrinkle Ridge in Aurorae Chaos. HiRISE/ NASA/JPL/University of Arizona]

05

THE HUMAN BODY IN SPACE

The Human Body in Space

Case Study: Separated by Space,

Space Healthcare

THE HUMAN BODY IN SPACE

The Apollo missions took 3 days to travel to the moon. The journey to Mars could take between 6 to 9 months and potentially to a year, which is a long time to be confined in a metal tube. There many types of hazards that face space travelers to mars. Extended periods of time in zero gravity will affect the normal functions of the human body; we were designed to function in Earth gravity. If tensions arise amongst the settlers, they will be stuck with each other for almost a year during the journey to Mars. When they arrive on the planet, they will live and work with those same people. Behavioral issues among people who are crowded into small space over a long time, no matter how well trained, are expected. If the mission crew do not get along, then the mission to Mars should be deemed as much a failure as a crash landing would be. The magnetic field and atmosphere of Earth protect the planet from solar radiation, in space, you are completely exposed. Being in small ecosystems for extended periods of time can play a big role in the everyday life of an astronaut; microorganisms that live in, or on someone's body can be transferred more easily in closed spaceship habitats, which makes foreseeing future medical problems an issue, as you can't pop out to the local pharmacy for medication.

The supplies that a mission to Mars is carrying with them is all they will be able to use in an emergency. Planning and self-sufficiency are key to survival when so far away from Earth. The mental and physical health of space travellers are keys to the success of living in space or on Mars.

The human body has developed to live on Earth, in 1G of gravity. In space there is 0G, weightlessness, and on Mars there is 1/3G. There are three gravity fields you would experience on a Mars mission. Transitioning from one gravity field to another is tricky, it affects your spatial orientation, hand-eye coordination, balance, movement, and you're likely to experience motion sickness. NASA has learned that without gravity working on your body, your bones lose minerals, with density dropping 1% per month, compared to 1% to 1.5% per year for the rate of typical bone loss on Earth. There is no guarantee that returning to Earth would mean 100% rehabilitation; your bone loss might not be corrected, so you could be at greater risk of osteoporosis-related fractures. If you don't exercise and eat properly, you will lose muscle strength, endurance, and experience cardiovascular deconditioning since it does not take effort to float through space.

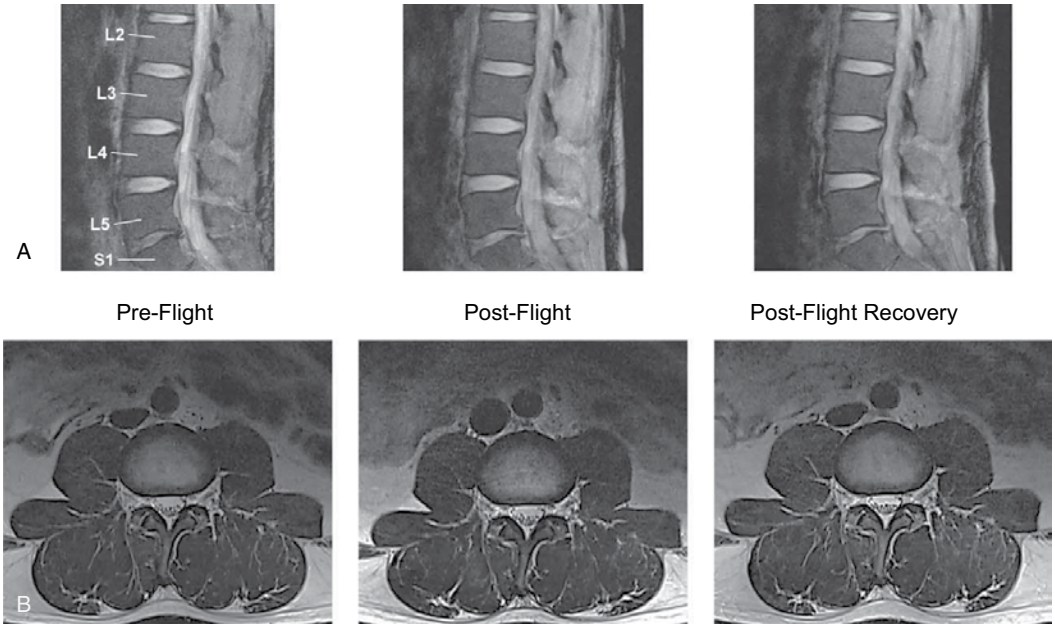
The fluids in your body will shift to your head, applying pressure on your eyes and causing vision problems. Your body becomes susceptible to develop kidney stones due to dehydration and increased excretion of calcium from your bones. Medications react differently with your body in outer space. Nutrition, including eating well, becomes important, otherwise health could be compromised.[13]

In space, everything floats, including internal fluids and organs. The human brain is surrounded by a protective cerebrospinal fluid in the skull (CSF). In space, the brain shifts upwards in the skull, thus displacing the CSF around the brain. Astronauts often complain of increased pressure in the head during missions, as well as changes in vision. It's possible that these brain changes may be contributing to those symptoms. More research is needed if people are going to get to Mars and aim to maintain 100% health. NASA is currently gathering significant information about the health effects of zero gravity: astronauts' bones and muscles weaken easily in space because people aren't working out these systems against gravity every day. Cerebrospinal fluid buffers the brain from shocks. Astronauts who had their brains scanned after their spaceflight, saw less of this fluid around the top of the brain, and more of it inside the brain's cavities.

They think that the brain may be pushing the fluid away from the top of the skull, leading to unknown cognitive changes. If we plan on getting to Mars with our brains in tact, more testing needs to be done to determine the effects of zero gravity. This requirement to provide artificial gravity for people could be the only way for travelling to Mars.

As everything in space floats, your vertebrae separate. Astronauts can grow up to 3% taller in space as the vertebrae separate. The spine is a giant spring, compressed on Earth while under the load of full gravity, keeping all the vertebrae tightly compressed. In space, with no gravity, there is no force acting down on the spine, therefore it stretches out. This is called Spinal Elongation. It occurs the moment you leave the Earth's gravity, up to a certain amount. When you return to Earth, your spine compresses, and you shrink to normal size.[14]

Dr. Sudhakar Rajulu at the Johnson Space Center's Habitability and Environmental Factors Office, the NASA office responsible for providing a safe environment for human spacecraft habitat, believes that there are reasons why the spine elongates. The first theory is that elongation only happens to the spine, elongation does not have a major effect on other areas of the body, such as the legs or arms.



[FIGURE 6 \\\\ Characteristic pre-, postflight, and recovery lumbar spine MR images (A) L1-S1 sagittal and (B) L3/4 axial T2 sequences.
Wolters Kluwer Health, Inc. 2016]

The spine is made up of discs that can compress, twist and move in all directions allowing for a versatile range of motion. Arm and leg bones are fixed pieces of bone that move at the joints and act independently, while the individual bones of the spine act together as one. The natural curve of the spine is straightened in space. Without the usual force of gravity pushing down on it, the spine is freer to relax. The second theory says that the discs between each vertebra are pressed together in regular gravity. This compression is due to the pressure pulling the spine downward. When gravity is lowered in space, the discs can hold more spinal fluid. This makes them larger. It also puts more space between each vertebra.[15]

In a recent study, NASA-funded, led by Drs. Alan R. Hargens and Jeffrey C. Lotz, it was found that spinal muscles may weaken during spaceflight, while there is no change in disc height between vertebrae. Six crew members who were aboard the ISS from 4 to 7 months, were studied immediately after they returned to the Earth as well as two months later.

MRI scans indicated significant decay of the paraspinal lean muscle mass, muscles that play a critical role in spinal support and movement, during the astronauts' time in space. The lean muscle, or "functional," cross-sectional area of the lumbar paraspinal muscles decreased by an average of 19 percent from pre-flight to immediate postflight scans. A month, or two later, only about two-thirds of the reduction had recovered.[16]

NASA already has ways for helping alleviate muscle mass loss through different exercises. Because it is the back muscles that are decaying, astronauts can do simple exercises that patients with severe back pain use on Earth to reduce the effects of spaceflight on the back.[17]

The body changes in weightlessness. NASA is using data collected on the ISS from returning astronauts to better understand and protect future astronauts against physical changes. Functional task testing will detect and minimize the effects of space on balance and performance.[18]

Fine motor skills testing is done to detect changes in your ability to interact with computer-based devices. The fluid distribution in the body can be monitored to evaluate connections to vision change. Compression cuffs worn on thighs will keep the blood in the lower extremities to counteract fluid buildup in the head. Self-evaluated fitness tests will assist in research on the decline in cardiovascular functions. Potassium citrate and other medicine help to combat the physiological changes that could increase the risk of kidney stones. Bisphosphonates drugs have shown to be effective in preventing bone loss. Collection and measurements of how much urine your body produces in space will provide key information about the astronaut's health. Proper nutrition, including vitamin D supplements since walking outside under the sun is out of the question. Regular exercise has been shown to keep the heart healthy, bones and muscles strong, mind alert, outlook more positive, and may even help with balance and coordination.[19]

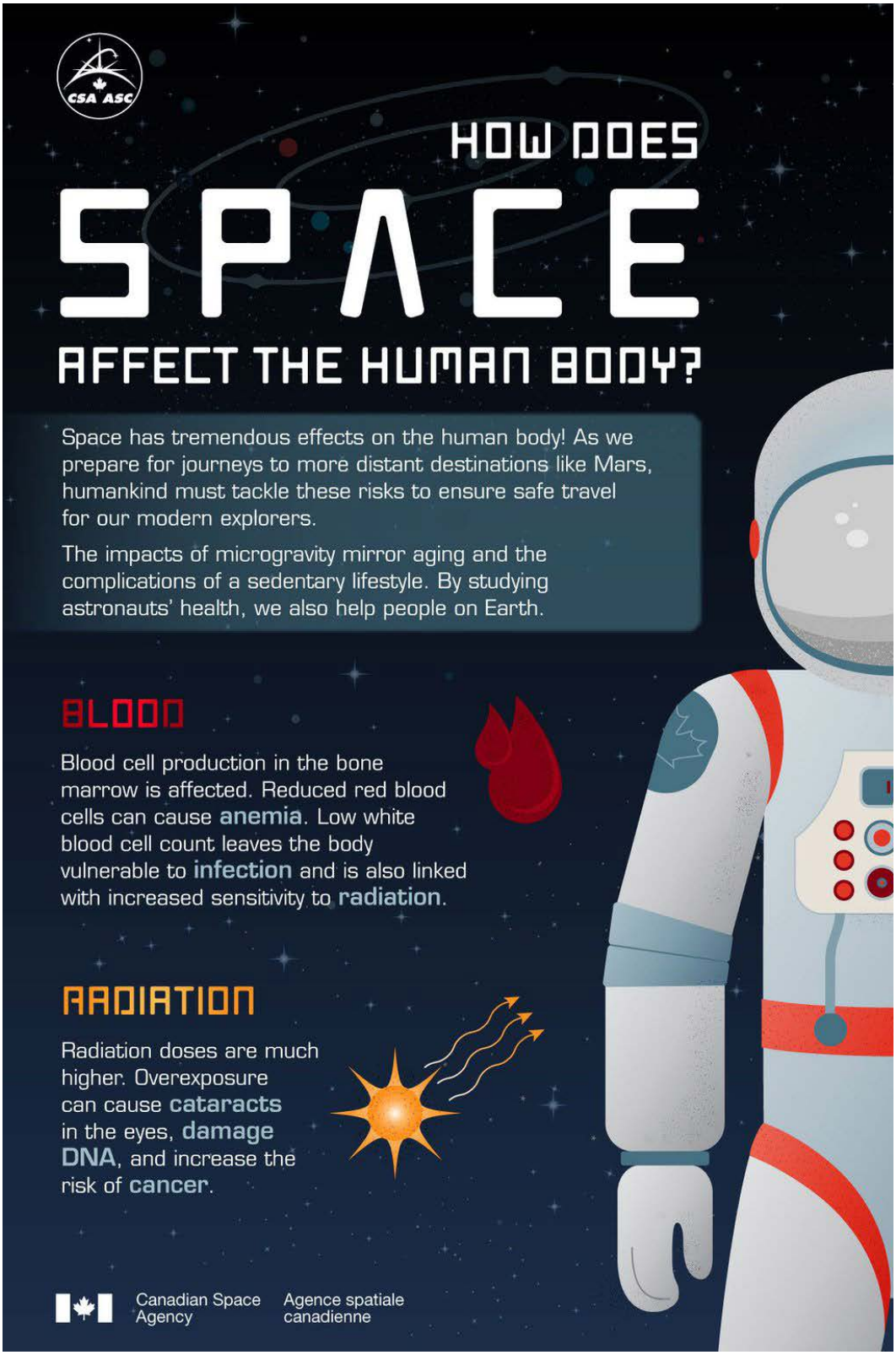
Another major health issue with space travel is the functionality of the immune system. Although we have the technology on Earth to play among the stars, our body is old, and after evolving for so long on the Earth, we aren't made to go into outer space. The human body is what is holding us back from reaching farther and farther away from home. The evolution of the human body has backed humanity into a corner of the Solar System.

After 6 months on the ISS, astronaut's blood samples are tested and analysed. Trying to understand the effect of microgravity on the protein make-up in the blood system, researchers found alarming changes to the immune system, suggesting that they would struggle to shake off even a minor virus, like a common cold – which is what killed the aliens in H.G. Wells', **"War of the Worlds"**. Results showed that in weightlessness, the immune system acts like it does when the body is infected and because the human body doesn't understand space, it turns on all its defense systems.[20] It has been known since the mid-20th century that microgravity influences metabolism, heat regulation, heart rhythm, muscle tone, bone density, and the respiration system. Samples of the astronaut's blood were taken 30 days pre-spaceflight ahead of their 6 months stay on the ISS and immediately taken when they landed back on Earth, and then taken again a week after their return.[21] [22]

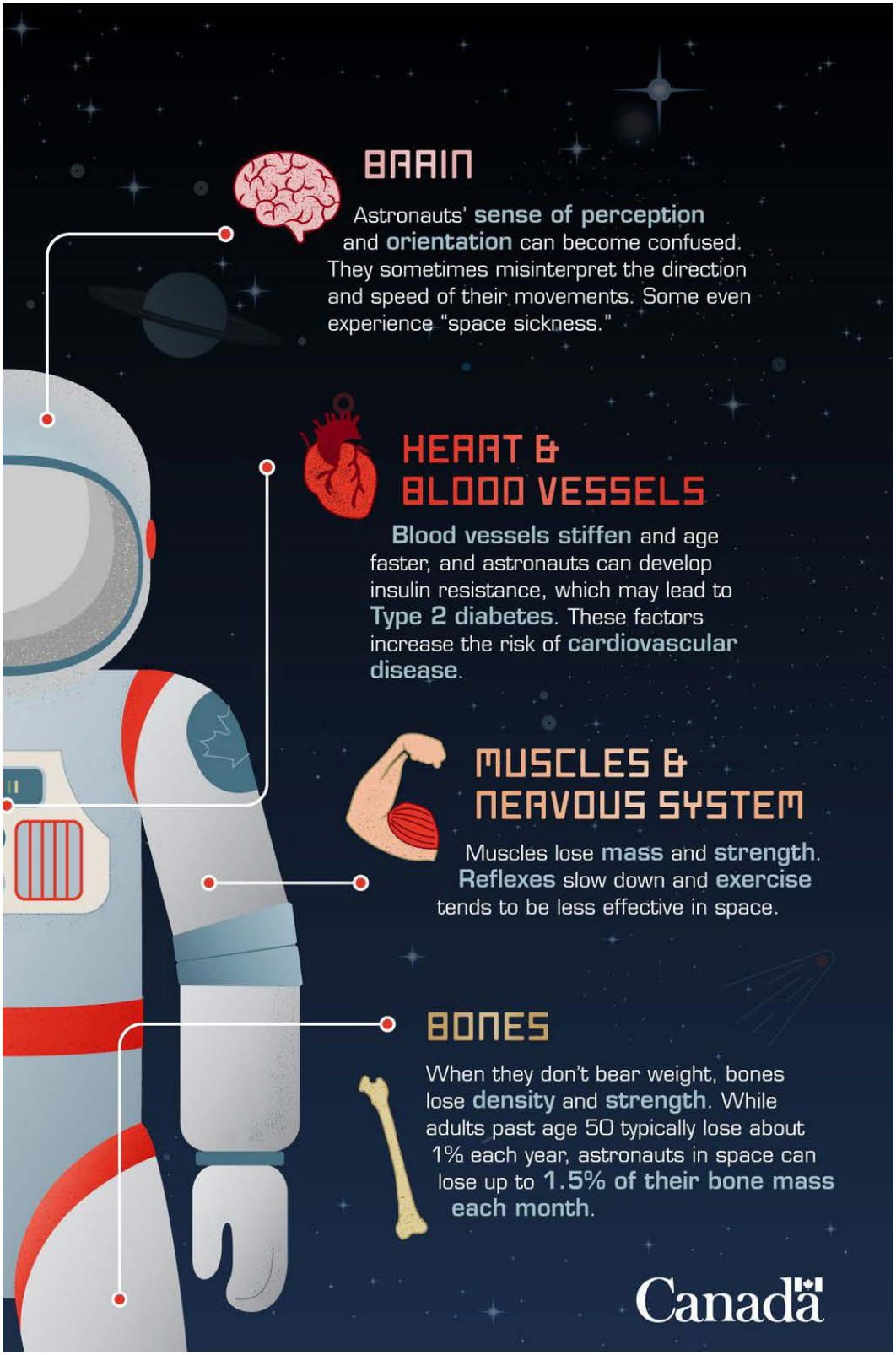
To fight the effects of space travel on the human body, NASA is considering epigenetic modification, gene editing. Epigenetic modifications would involve altering the way genes are read without changing the actual DNA code. This would be achieved by altering chemicals that control gene volumes, so their activity could be silenced or amplified in a given situation. Genes could also be changed to boost the cell resilience, making cancer and radiation-related issues preventable.[23]

Currently, travelling through space is done in small metallic tubes. NASA has learned that by sticking people together in cramped conditions for extended periods of time, no matter how well trained, will develop behavioral issues. Crewed missions to Mars will be confined for 6-9 months in close quarters, potentially encountering a decline in mood, slow cognition, low morale, or problematic social interaction. The development of a sleep disorder may arise from the noisy environment of the space craft, the stress of prolonged isolation and confinement, or the extra 38 minutes in each Martian day. Depression could occur. Fatigue is inevitable because of heavy workload and shifting schedules, however periods of downtime may lead to boredom. Misunderstandings and impaired communications with crew members might impact performance and mission success.[24]

A lack of fresh food and variety, or deficiency in nutrition, may further contribute to physiological and cognitive decline. More autonomy will be required due to the communication delays over the vast distances from the space vehicle to Earth (20-minute delay in communications on Mars). There is even the possibility of the third-quarter effect, where morale and motivation decline three-quarters of the way into a mission, regardless of how long the mission lasts.[25]



[FIGURE 7.A \\\\ How does Space affect the Human body? CSA, 2018]



[FIGURE 7.B \\\\ How does Space affect the Human body? CSA, 2018]

CASE STUDY: SEPARATED BY SPACE

Astronauts, and identical twin, Scott and Mark Kelly, are subjects of NASA's Twins Study. Comparing what happened to astronaut Scott Kelly, who was in space and to his identical twin brother, Mark, who remained on Earth. A nature versus nurture study. Typical stays on the ISS are 6 months long, Scott was up there for one year. By measuring large numbers of metabolites, cytokines and proteins, researchers learned that spaceflight is associated with oxygen deprivation stress, increased inflammation, and dramatic nutrient shifts that affect gene expression. Another interesting finding concerned what some call the "space gene", found only after spaceflight, which are thought to be caused by the stresses of space travel.[26] Researchers know that 93% of Scott's genes returned to normal after landing. However, the remaining 7% point to possible longer-term changes in genes related to his immune system, DNA repair, bone formation, hypoxia, and hypercapnia.[27]

SPACE HEALTHCARE

NASA has been developing methods and technologies to counteract issues that may arise during space flight. Actigraphy devices that collect data on astronaut's sleep, as well as developments in LED technology can to improve sleep and alertness by recording how much you move during your sleep and how much ambient light is around you. Journals give a safe place for astronauts to vent frustration, giving insight on behavioural issues amongst a crew.[28]

Architecture must play a role in helping crews cope with isolation and confinement. As architects, we design spaces for people to live in. Can architects, engineers, and psychologists work together towards the design details of your living and working quarters in outer space? Spaces must be designed so crews do not feel trapped in the environments they work and live in. Microbes change characteristic when in space and microorganisms living on someone's body can easily transfer from person to person in closed systems. Space is a stressful place to be in, stress levels and the immune system can be altered, leading to vulnerability to allergies, illnesses, or disease.[29]

Monitoring the air quality, of a settlement or spaceship, and the urine and blood of crew members regularly is key to ensure that the atmosphere is safe to breathe and not contaminated with gases like carbon monoxide. Monitors in toilets can test to ensure the stress of space flight hasn't caused infectious illnesses like the Epstein-Barr virus (Mono).[30]

Solar radiation is one of the most dangerous aspects of space travel. Even within the magnetosphere of the Earth, astronauts in the ISS still receive up to ten times the radiation than what hits the surface of the Earth. Damage to the central nervous system, showing itself as altered cognitive function, reduced motor function, and behavioral changes also occur. Space radiation can cause radiation sickness, resulting in nausea, vomiting, anorexia, and fatigue. You could develop degenerative tissue diseases such as cataracts, and cardiac and circulatory diseases. The food you eat and the medicine you take must retain their nutrient and pharmaceutical value, even while being bombarded with space radiation. A vehicle traveling to Mars and a habitat on Mars will need significant protective shielding.[31]

To fight radiation, NASA is shielding, monitoring and following operation procedures to control radiation risks to acceptable levels to keep astronauts safe. Like shielding on Earth, NASA is developing a superconducting magnetic shielding system. [32]

These magnetic shields can create intense magnetic fields with little, or no electrical power input, and with proper temperatures they can maintain a stable magnetic field for extended periods of time. One challenge is developing a system that can create a magnetic field large enough to protect a bus-sized, habitable spacecraft. Another challenge is keeping the system at temperatures near absolute zero, which gives the materials their superconductive properties.[33] In **"Journey of a Robotic Architect"**, a new type of transparent glass is said to filter cosmic radiation through multi-laying of films and layers with infills of gas and liquid water. This technology is speculative but derived from glass technology used in material science today.

Mars is 400 million kilometres away from the Earth, planning and self-sufficiency are key to successful Mars expeditions. Communications are delayed by twenty minutes and possible equipment failure would force settlers to improvise and use what is at hand. Food and medicine would have to remain good to consume for extended periods of time before a resupply would reach them on Mars. NASA examines the types of medical events that happen in space over a six-month period and determines the types of skills, procedures, equipment, and medication that are needed.

That information is a good indicator of how many supplies will be needed for a journey to Mars. [34]
NASA is studying and improving food formulation, processing, packaging, and preservation systems to ensure the nutrients remain stable and the food remains acceptable.[35]

On Earth, our daily activities are defined by when the sun rises and sets. The idea of a "day" aboard the ISS is abstract. Over the course of 24 hours, astronauts on board of the ISS experience 16 sunrises and sunsets as the station orbits Earth. Astronauts work and sleep to fixed schedules that match their internal clocks. Any other arrangement would have crews living in a state of permanent jet lag. When travelling to Mars, the only indication of day and night will be clocks onboard the space craft taking you to the Red planet. Ambient lighting would be key in convincing your brain and body of the time of the day, whether its "morning," or "night". One Martian day is 24 hours, 39 minutes, and 35 seconds.[36]

In the Mars trilogy, **"Red Mars"**, the settlers adopt the Martian solar day but adjust it the length of an Earth day, so it does not become confusing when communicating with the Earth. The 39 minutes and 35 seconds at the end of every sol is negated. When the clocks hit midnight on Mars, time freezes for 39 minutes and 35 seconds, then the clocks resume at 00:01 UTC.[37] On the ISS, astronauts strap their sleeping bags to a sleeping post on the wall during the night. Sleep spots are placed in line with a ventilator fans because warm air does not rise in space, therefore astronauts in badly-ventilated sections end up surrounded by a bubble of their own carbon dioxide resulting in oxygen starvation.[38] Over time, crew members are reassured and acclimatise to the background sound of the life support systems.

For successful space travel and living in low gravity on Mars, the health of the human body is difficult to maintain with the lack of gravity and constant bombardment of cosmic radiation. The simplest way of maintaining our health whilst in space flight is by ensuring the proper intake of nutrients. Space food has improved in taste and variety since the freeze-dried meals of the Apollo missions. But space meals are prepared and eaten under the same basic restrictions: food and drink have to be confined, or crumbs and liquid droplets will wander off around the station.

This is messy and unhygienic; but if free-falling food gets into station equipment, it can also be dangerous, therefore liquids are served in plastic bags and sipped through straws. Extensive time in microgravity dulls taste-buds, so spicy food is a favourite among astronauts. The food would have to be stored properly and be non-perishable to avoid spoilage. Astronauts prepare their meals and dispose of garbage on their return. Depending on the type of food, some foods can be eaten in their packaged/natural forms (brownies/fruit). Whereas other foods need water (macaroni and cheese, pasta). There are ovens on the ISS, but no refrigerators, so space food must be stored and prepared properly to avoid spoilage, especially on longer missions.[39]

In Star Trek, they use a device called a Replicator. The machines can create (and recycle) objects. Replicators were originally seen used to synthesize meals on demand, but in later series they took on many other uses.[40] Similar to 3D printers, a replicator works by rearranging subatomic particles, which are abundant everywhere in the universe, to form molecules and arrange those molecules to form any object, edible, or not. The difference is that 3D printers are limited to materials that easily fuse together via extrusion, or sintering processes; plastics, metals, and clays.[41] However, food, concrete, even organs and a few other materials have been successfully printed on limited scales. The replicator is used to provide food and water on board starships, thus eliminating the need to stockpile supplies. Starships and star bases, stock emergency provisions, in case of replicator failure. On Star Trek: Deep Space Nine, it was established that as long as there is an energy source to power life support, replication is used to provide breathable air and to disassemble the carbon dioxide exhaled by the crew, thus providing a seemingly endless supply of oxygen and eliminating the need to carry air tanks.[42] The technology is also used for producing spare parts, which makes it possible to repair ship damage without having to return to a star base.[43]

3D printing has become mainstream, anyone can easily make small parts, or models by downloading or designing them. A NASA funded project hopes to prototype a 3D food printer, or as they call it, "a universal food synthesizer", that could save on cargo space and supplies while keeping astronauts healthy on long-term missions. Long distance space travel requires 15-plus years of shelf life. Fresh foods wouldn't survive well in storage, so dehydrating all the carbs, proteins and macro and micro nutrients turn them into powder form, making them last maybe 30 years.[44]

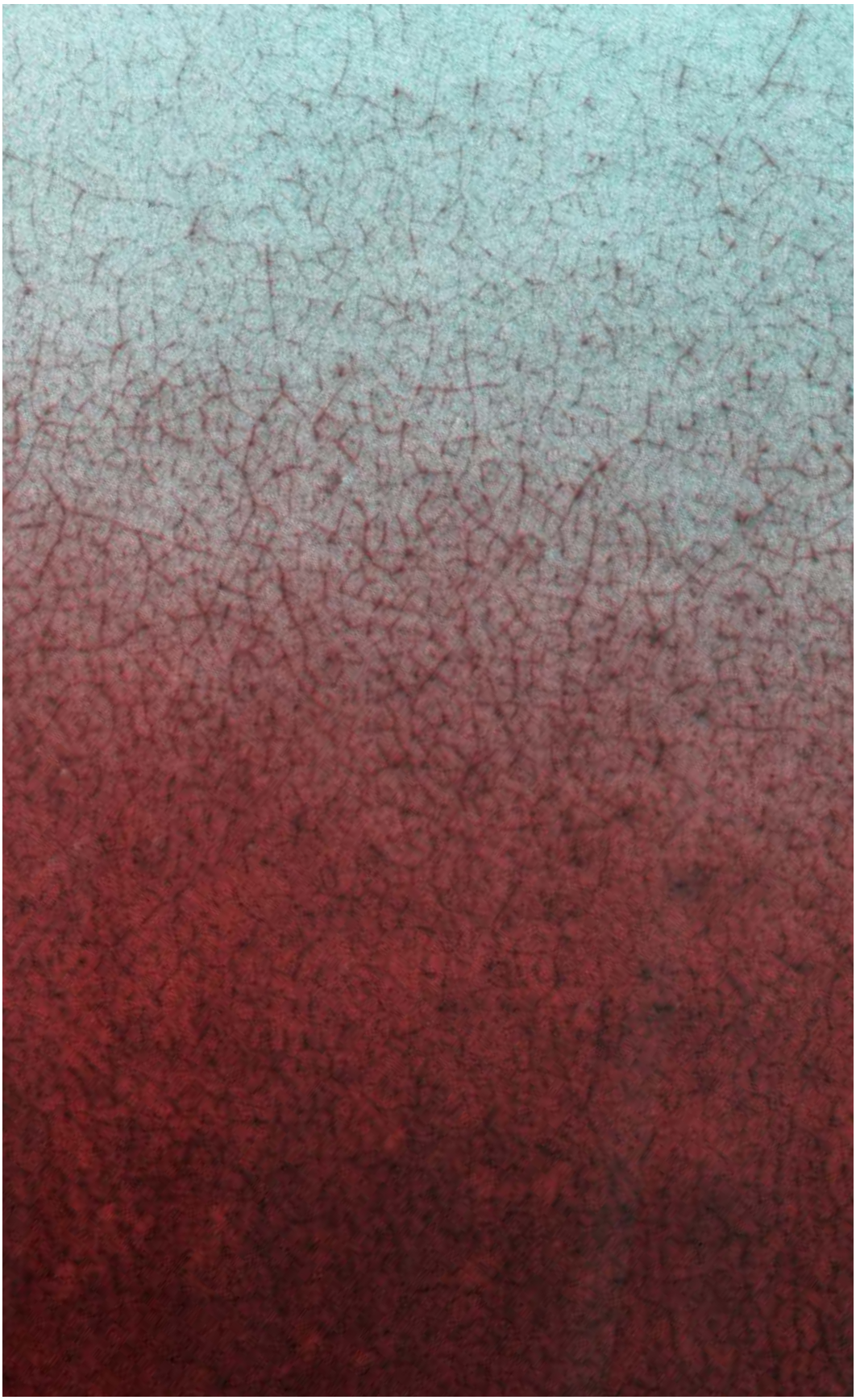
When using toilets during space travel, no water is used. Astronauts must fasten themselves to the toilet seat, while a powerful fan and a suction hole slide open, and the air stream carries the waste.[45] In Stanley Kubrick's **"2001: A Space Odyssey"**, the "Zero Gravity Toilet" instructions are alleged to be the only intentional joke in the film, however the instructions (Appendix B) are detailed, and describe a plausible lavatory suited for space flight. The instructions are seen momentarily during Dr. Heywood Floyd's flight to the Clavius base on the Moon aboard the PAN AM Aries spacecraft. [46]

In science fiction, a common solution to long term space travel is cryogenic sleep. Astronauts are suspended in a low metabolic state/sleep in stasis pods where vital functions are kept to a minimum by cooling the body. Sci-fi movies like the **Alien** franchise, **2001: A Space Odyssey, Passengers, Interstellar, The Fifth Element** and others, have employed these pods.

Even though it might seem like the most speculative science fiction technology, stasis chambers may become working reality in the next three decades. According to a NASA-funded study, it will be possible to keep an astronaut unconscious in these pods almost half the time of any given trip. The pods are fully automated and monitor the vital signs of the astronaut as they sleep. When the crew are placed in an inactive state, many of the ship's subsystems and equipment needed for humans is significantly cut down.[47] The negative psychological and social aspects of prolonged space travel could be mitigated. The solution involves mimicking torpor; short-term hibernation. To achieve torpor, stasis pods would become the habitat inside the spaceships where the astronauts can hibernate for much of their voyage. Inside the pressurized chamber up to six crew members could co-exist in the low metabolic state simultaneously.

Torpor would be induced by an assisted hypothermic state in which the body is slowly cooled, sensors on the astronaut's body monitor their condition and trigger automatic safety mechanisms in case something goes wrong. "Food" would be administered intravenously through TPN – total parenteral nutrition. A catheter would be inserted to drain urine and thus handle all waste, since bowel is rendered inactive because there's only liquid nutrition. Waking out of cryogenic sleep after 6 months of slumber might sound like the worst hangover in the universe, so electromagnetic muscle stimulation would prevent muscle atrophy.[48]

In **"Journey of a Robotic Architect"** there are no humans in the story line. Control gives to the main character, Mars Colonizer Mobile Doll B22, also know as the "Architect", a brief history of why there are no people on Mars, explaining that the human body is too fragile for extended periods of space travel. **"The Medical Logs of Dr. Eir"**, further prove the hardship that the human body endures during space flight. The failed manned missions to Mars are replaced by machines.



[South Polar. HiRISE/ NASA/JPL/University of Arizona]

06

MARS, THE RED PLANET

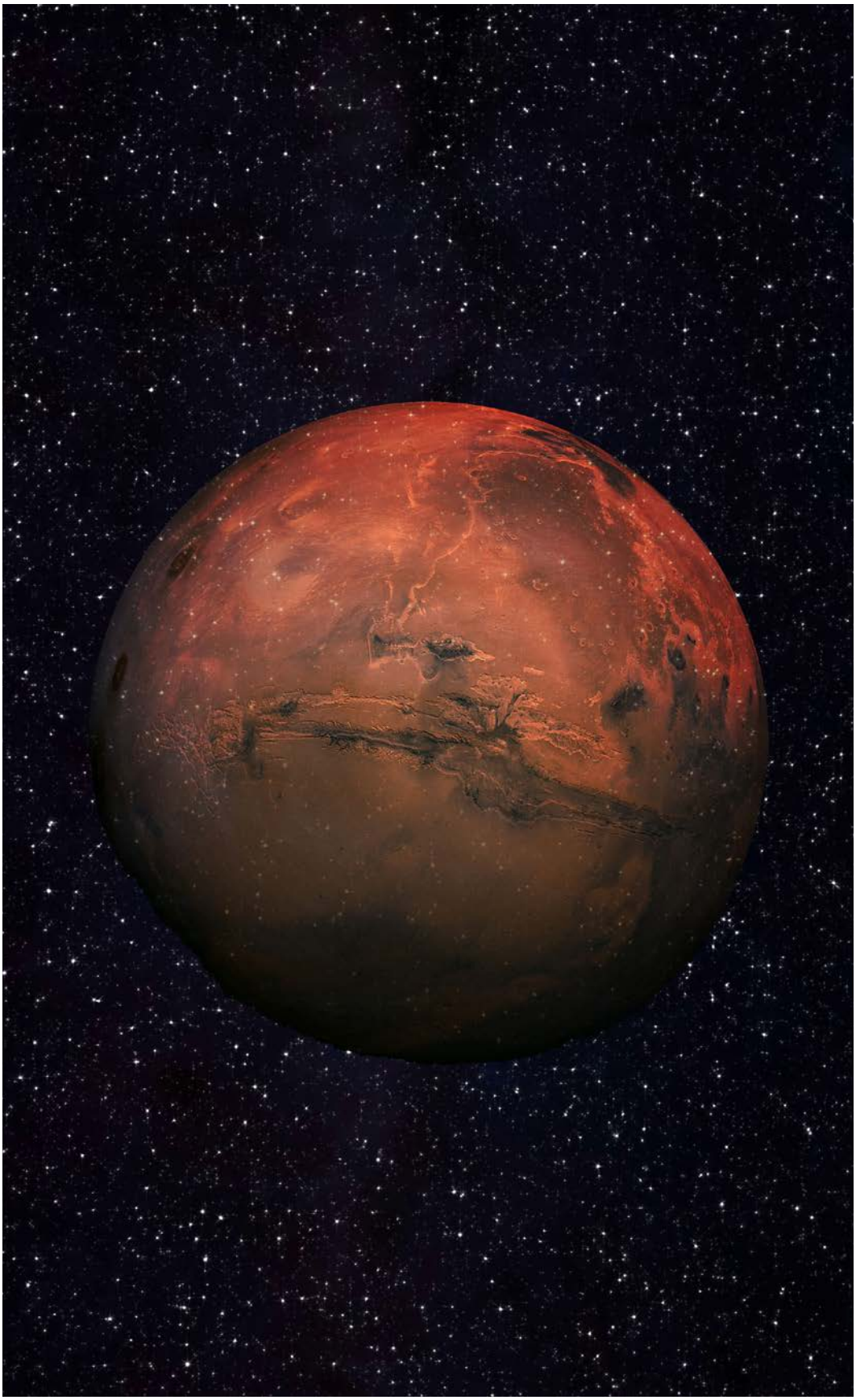
Mars, The Red Planet

SpaceX and Starships

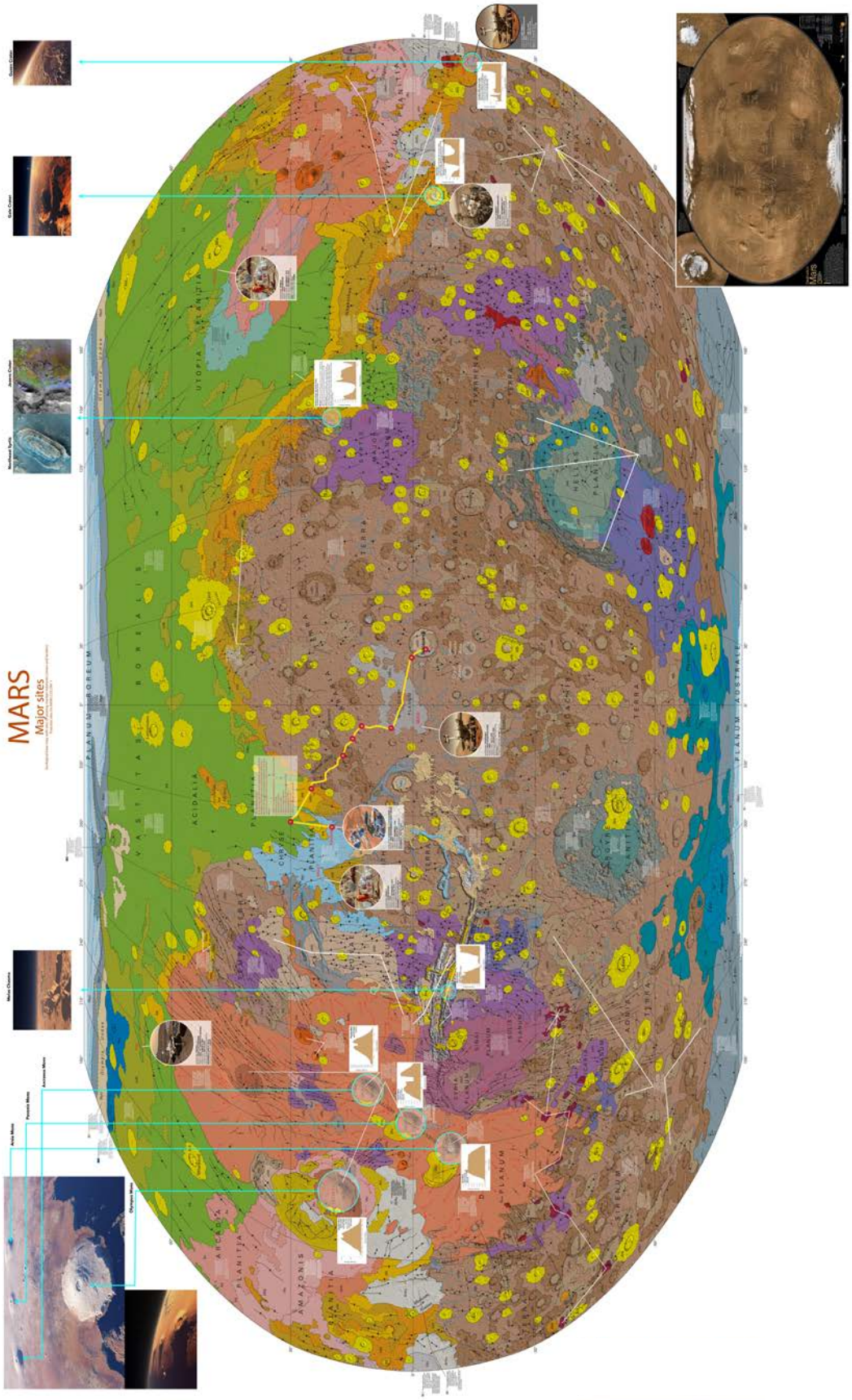
Craters and Mons: Landscapes of the Martian Surface

Infrastructure and Terraforming;
Make Mars blue again

Inhabit vs Colonize



[FIGURE 8 \\\\ MARS. Viking Orbiter. NASA/JPL-Caltech/USGS, 1998]



[FIGURE 9 \\\\ Geological Map of Mars. USGS. Modified for Colloquium 1.
Tanaka, K.L., Skinner, J.A., Jr., Dohm, J.M., Irwin, R.P., III, Kolb, E.J.,
Fortezzo, C.M., Platz, T., Michael, G.G., and Hare, T.M., 2014, Geologic map of Mars:
U.S. Geological Survey Scientific Investigations Map 3292, scale 1:20,000,000, pamphlet 43 p.,
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MARS, THE RED PLANET

Mars has been a subject of exploration throughout human history. In ancient times, it was named after the Roman God of War. In Babylonian astronomy, the planet was named after Nergal, their deity of fire, war, and destruction.[49] Mars in modern day fiction was first seen in **"Across the Zodiac"** (1880) written by Percy Greg, where the character in the story, the narrator, flies his craft, the "Astronaut," to visit tiny beings on Mars. From an early time in humanity's early understanding of the cosmos, people have dreamed about travelling to Mars. Later in the 20th century, writers began exploring the colonization of Mars, creating vast utopian cities, often in much the same way that early European explorers did when they travelled to North and South America, bringing destructions to the native inhabitants, much like in **"What Mad Universe"** (1949) by Fredric Brown. There are still no signs of intelligent life on Mars, so it won't be the same as on Earth. Mars will be a clean slate.

NASA's Mars Exploration Program seeks to understand whether Mars was, is, or can be a habitable world. Missions like Mars Pathfinder, Mars Exploration Rovers, Mars Science Laboratory and Mars Reconnaissance Orbiter, among many others, have provided important information in understanding of the habitability of Mars. This poster imagines a future day when we have achieved our vision of human exploration of Mars and takes a nostalgic look back at the great imagined milestones of Mars exploration that will someday be celebrated as "historic sites."

NASA Jet Propulsion Laboratory
www.jpl.nasa.gov

[FIGURE 10 \\\\ Mars Exploration Tourist Poster. JPL Visions of the Future Posters.
NASA/JPL-Caltech. 2018]

The fourth planet in our solar system, Mars is our nearest planetary neighbour at only 56,000,000 km apart at its closest orbit to the Sun. It is often referred to as the "Red Planet" because the reddish iron oxide is dominant on its surface, which gives it a reddish appearance that is distinctive among the astronomical bodies visible to the naked eye. Mars is a terrestrial planet with a thin atmosphere, having surface features reminiscent of both the impact craters of the Moon and the valleys, deserts, and polar ice caps of the Earth.[50] Mars is approximately half the diameter of the Earth with a surface area only slightly less than the total area of the Earth's dry land. Mars is less dense than the Earth, having about 15% of the Earth's volume and 11% of the Earth's mass, resulting in about 38% of the Earth's surface gravity.[51]

The rotational period and seasonal cycles of Mars are like those of the Earth, as is the tilt that produces the seasons is like Earth's. Mars's average distance from the Sun is roughly 230,000,000 kilometres and its orbital period is 687 (Earth) days. A sol (Solar day) on Mars is only slightly longer than an Earth day: 24 hours, 39 minutes, and 35.244 seconds. In the Mars trilogy by Kim Stanley Robinson, three books, **"Red Mars"**, **"Green Mars"** and **"Blue Mars"**, chronicle the settlement and terraforming of Mars. The first astronauts to settle on the plane decide to pause time every night during the extra 39:35 after the 24 hours of the day in order to keep days on Mars the same as days on the Earth.

With Mars' proximity and likeness to the Earth, it is logical to choose it as the next planet for humanity to visit. However, Venus is more similar to the Earth than to Mars, and it is closer to the Earth. But the surface of Venus is said to resemble traditional accounts of hell. Venus is sometimes called Earth's "sister planet" because of their comparable size, mass, proximity to the Sun, and composition. Venus's atmospheric pressure on the surface is 92 times that of the Earth, roughly the pressure found 900 m (3,000 ft) under sea level and consists of more than 96% carbon dioxide. Venus is the hottest planet in the Solar System, with a mean surface temperature of 462 °C even though Mercury is closer to the Sun. Venus is shrouded by an opaque layer of highly reflective clouds of sulfuric acid, preventing its surface from being seen from space in visible light. It is speculated that it may have had water oceans in the past, but that these would have vaporized as the temperature rose due to a runaway greenhouse effect. Any water on Venus would have photo-dissociated, and any free hydrogen would have been swept into interplanetary space by solar winds because of a lack of a planetary magnetic field. Venus's surface is a dry desert-scape scattered with slab-like rocks and is periodically resurfaced by volcanism.

Life on Venus would require architecture and technology designed for the most extreme landscapes, high heat and high pressure, as well as a protective outer shell to defend against sulfuric acid rain. If you were able to walk on Venus, it would be deadly; you would suffocate, be crushed to death, and your remains would be incinerated by the heat and dissolved by the sulfuric acid.[52] Venus is a prime example as to what could happen if humanity was to continue polluting the Earth.

Mars is not a perfect candidate for humans but it is safer than Venus. In terms of how difficult it would be to begin terraforming the planet, it is easier to add greenhouse gases into the atmosphere than remove it. Mars was once a wet planet like the Earth is today, with oceans and rivers once running along the surface of the planet long vanished. Mars today is a frozen desert, barren of life. It is believed that microbial life may have thrived billions of years ago or may even still live underground in hot springs.

The Apollo missions went to the Moon in 3 days. Getting to Mars will take approximately 6-9 months, or up to a year, depending on where the planets are in relation to each other when the mission launches. To get to Mars, NASA (in July of 2009) predicted approximately 1.5 million pounds of equipment would need to be sent to Mars.

That is more weight than the International Space Station, which costs $100 billion dollars. To save weight on food and water, the astronauts would have to purify their waste, then use it to fertilize plants during the trip and while on Mars.[53] With none of those things available on Mars, we must bring them from the Earth. Living off the land of Mars will be impossible, there is no oxygen, no liquid water, no animals, and no plants. The atmosphere is almost entirely carbon dioxide with an atmospheric pressure that is only 1% that of the Earth. Not an ideal location to move to.

Fuel is another Earthly resource that will need to be brought to Mars if the first rockets wish to return to the Earth. This means that several steps are needed to go to and return. Several supply missions with infrastructure, equipment, and supplies will need to be sent to the planet prior to humans touching ground. In **"Journey of a Robotic Architect"**, it is described that humanity tried to settle by sending a group of astronauts/settlers to begin building on Mars. After the human failure to settle, humanity sends robots to build settlements before the arrival of the next humans. Such precautions are being made by SpaceX when they send their first drone ships to Mars. Those ships will carry factories for turning methane and carbon dioxide into rocket propellant that will fuel the rockets for future missions as well as machinery.

Again, referring to the **Mars trilogy,** UNOMA (United Nations Organization Mars Authority) sends all the heavy equipment to Mars prior to the manned mission of the first hundred. They sent diggers, lifters, heavy machines, atmosphere separators, water collectors, years before the manned mission. This thesis utilizes the same concept, but to a larger scale. Having machines and robots build the actual settlements for the humans, before they arrive so they can move into a partial, or fully functional settlement.

[FIGURE 11 \\\\ Explorers Wanted on the Journey to Mars.
"Hike the solar system's largest canyon, Valles Marineris on Mars, where you can catch blue sunsets in the twilight, and see the two moons of Mars (Phobos and Deimos) in the night sky".
NASA/KSC. 2009]

SPACEX AND STARSHIPS

The Space Race of the 20th century has been a competition between the United States (US) and the Soviet Union (USSR) during the cold war to show technical dominance in spaceflight post WW2. The technological superiority required for such dominance was necessary for national security and became symbolic of ideological superiority. The Space Race spawned pioneering efforts to launch artificial satellites, unmanned space probes, to the Moon, Venus, and Mars, and human spaceflight in low Earth orbit and the Moon.[54]

"The cold war would become the great engine, the supreme catalyst, that sent rockets and their cargoes far above Earth and worlds away. If Tsiolkovsky, Oberth, Goddard, and others were the fathers of rocketry, the competition between capitalism and communism was its midwife."

- William E. Burrows, 1998 [55]

The driving factor of the early space programs was the cold war and the rivalry between superpowers. Both governments were prospering in a post WW2 age and spending on national budgets (5.5% of the US federal budget was spent on the Apollo program) did not matter because national pride was at stake, as well as military and technical superiority. That was not a sustainable figure to pour into the space program and funding eventually collapsed. In recent years, the price of space travel has dropped as more private firms and entrepreneurs inject energy, money and enthusiasm into the next space race. Companies like SpaceX, Virgin Galactic and Blue Origin are creating new enthusiasm around the world to reach out into the stars with ideas of visiting space for tourism or launching a Tesla Roadster towards Mars. Rockets and space architecture capable of interplanetary travel, like the Space Launch System (SLS) from NASA and SpaceX's Falcon Heavy booster are planned to take explorers back to the moon, to Mars and beyond.[56]

The first travelers to Mars will be in crews of four to six, traveling inside large metal cans linked together, with solar panels extending out like sails. Each space craft will be about the size of a small two-bedroom house, which seems large until you factor in all the supplies and science equipment needed for the years-long mission. The design of the space craft will have to consider the happiness, productivity, and overall mental health of a crew for up to a year.

Elon Musk has said that the goal of SpaceX is to get humans to Mars and ensure the basic infrastructure for the manufacturing of rocket propellant and the survival of the first settlers. Musk compares the work that SpaceX is doing as the equivalent of building the transcontinental railway across America. Terraforming and making the planet habitable will be a multidisciplinary and multinational effort, with the help of many companies, thousands of people and billions of dollars.[57]

The first rockets that go to Mars will be drones. In fact, the first object sent to Mars was the USSR MARS 1 orbiter in November of 1962, a probe with instructions to orbit the planet and relay information back to Earth, but it had lost contact during its journey. The first man made object to reach the surface of Mars was the USSR MARS 2 orbiter and lander in 1972, but it crashed on the surface. The first successful man-made object to hit the planet was the NASA lander and rover combination of Pathfinder and Sojourner on July 4th, 1997.[58]

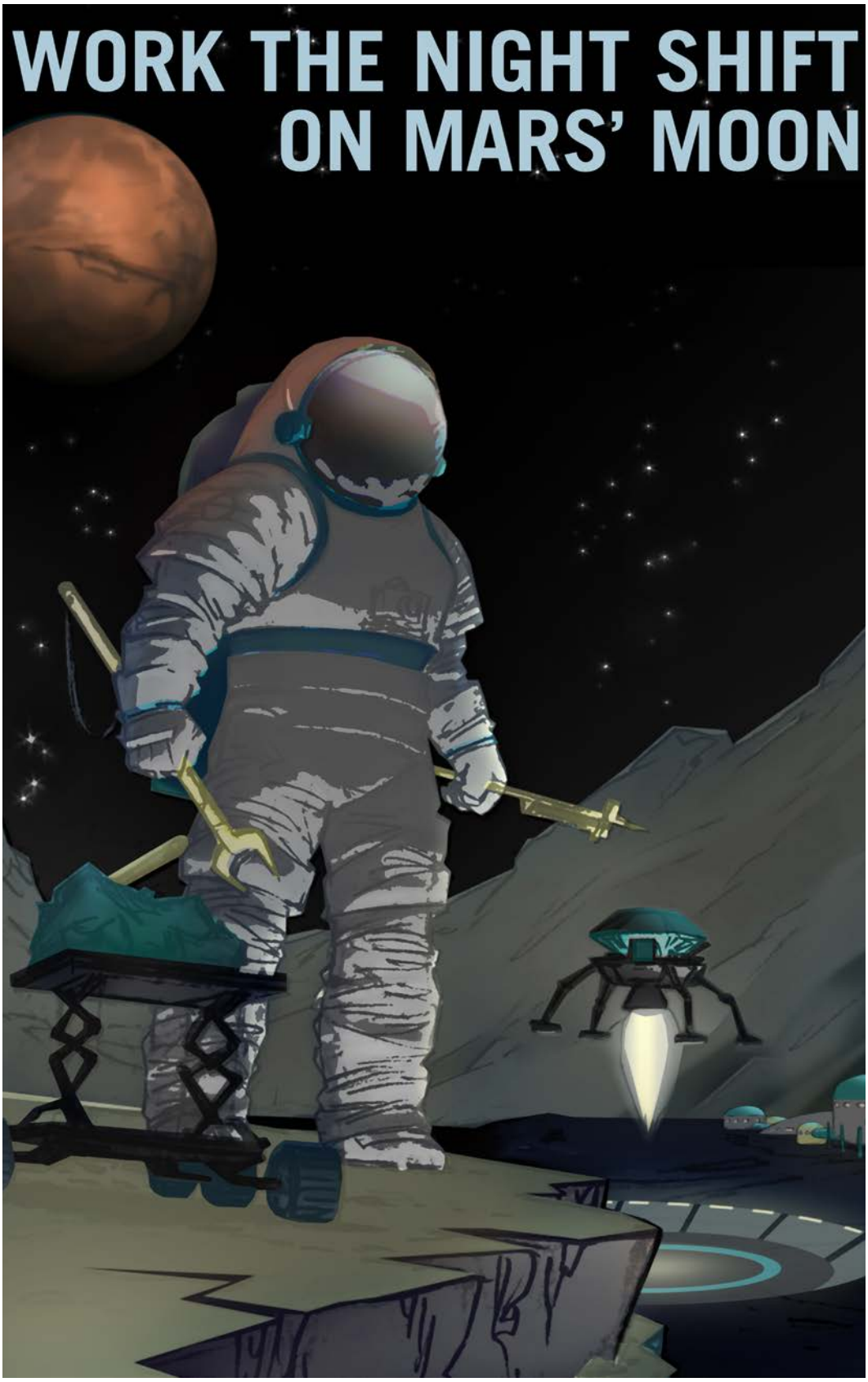
As part of the Interplanetary Transport System from SpaceX, supply ships will travel to Mars prior to manned missions; carrying equipment, machinery, and supplies. Carrying extra rocket fuel for a return journey to the Earth would increase cost, so SpaceX plans to use resources on Mars to produce rocket fuel. Early ships will carry mini factories that will produce fuel from the natural resources on Mars.

The fuel should be simple to produce on Mars given its carbon dioxide atmosphere, water-ice reserves and abundant methane. SpaceX's rocket technology is based on the idea that recycling keeps costs low. The first stage segments of the Falcon 9 rockets have successfully demonstrated their ability to land themselves back safely on the ground, or at sea on barges. The Falcon Heavy, a second generation rocket from Space X, is a partially reusable super heavy launch vehicle derived from the Falcon 9 vehicle and consists of a strengthened Falcon 9 first stage as a central core with two additional first stages as strap-on boosters. The maiden voyage of Falcon Heavy in February 2018, launched with a test payload, more publicity stunt, of Elon Musk's personal midnight cherry red Tesla Roadster. Inside the vehicle was a mannequin in the driver's seat wearing a SpaceX spacesuit, named Starman, to reference David Bowie's song **"Starman"** from the 1972 album **"The Rise and Fall of Ziggy Stardust and the Spiders from Mars",** all while the car plays "Space Oddity" (1972) on loop, even though sound cannot be heard in space. A copy of Douglas Adams' 1979 novel **"The Hitchhiker's Guide to the Galaxy"** sits in the glovebox, alongside a towel (in references to The Guide), and a sign on the dashboard that reads **"Don't Panic!"**. A Hot Wheels miniature Tesla Roadster with a miniature Starman inside is mounted on the dashboard. A message on the vehicle's circuit board reads "Made on Earth by humans".

[FIGURE 12 \\\\ Elon Musk's personal Tesla Roadster with Starman sitting in the driver seat travelling through space. SpaceX. 2018]

These references to different forms of science fiction demonstrate the influence that science fiction has on the world, either making nods to different authors or artists through using names of characters or using iconic moments of the science fiction to pay homage to.

SpaceX's flag-rocket will be the BFR Starship (Big Falcon Rocket), a two-stage rocket where the upper stage is used as a spacecraft to take people to Mars and back. To achieve a large payload, the spacecraft first enters Earth orbit, where it is refuelled before it departs to Mars, then orbits the earth to use a slingshot to gain speed. After landing on Mars, the spacecraft is loaded with locally produced fuel to return to the Earth.[60] SpaceX hopes to use the single range of the vehicle for Earth-orbit, Lunar-orbit, interplanetary missions, and intercontinental passenger transport on Earth, via space.



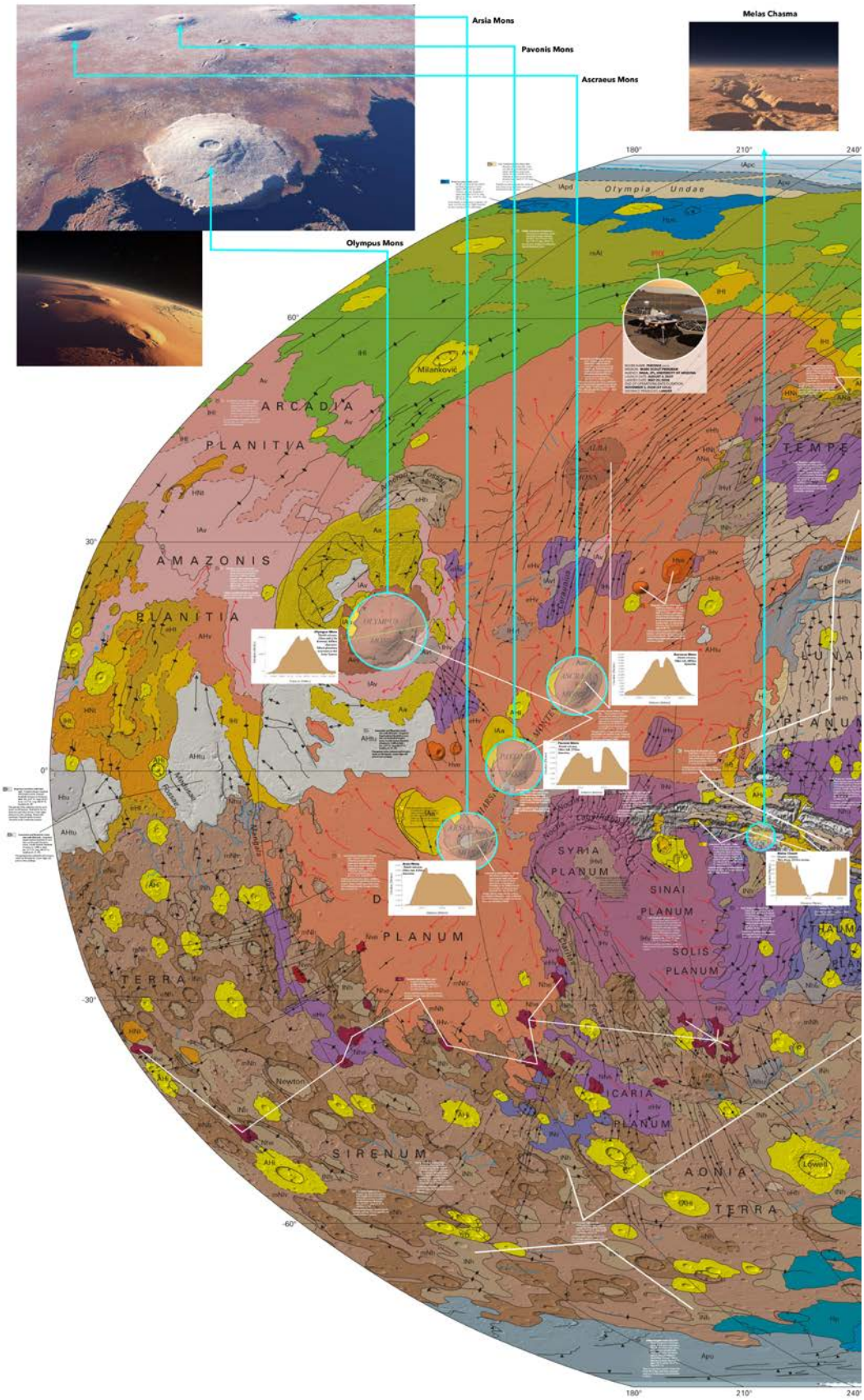
[FIGURE 13 \\\\ Work the Night Shift on Martian Moon Phobos.
"Night owls welcome! If you lived on Mars' moon Phobos, you'd have an office with a view, mining for resources with Mars in the night sky. Settlers below on Mars would see Phobos rise and set not once, but twice in one day!"
NASA/KSC. 2009]

CRATERS AND MONS: LANDSCAPES OF THE MARTIAN SURFACE

\\\\ MARS, THE RED PLANET

The Martian landscape varies considerably: the northern plains flattened by lava flows contrast strikingly with the southern highlands, pitted and cratered by ancient impacts. In "Journey of a Robotic Architect", the Architect's adventures take him on a trek through the many landscapes of Mars and discovers the many settlements that have been build by the machines. The biggest areological features on Mars are the craters, volcanoes and vast valleys. Each landform has its own advantages and disadvantages for becoming a site to settle.

The surface of Mars as seen from Earth is divided into two kinds of areas, with differing albedo.[61] The paler plains covered with dust and rich sand, reddish iron oxides, were once thought of as Martian 'continents' and given names like Arabia Terra (land of Arabia) or Amazonis Planitia (Amazonian plain). The dark features were thought to be seas, hence their names Mare Erythraeum, Mare Sirenum and Aurorae Sinus.[62] Research in 2008 has presented evidence regarding a theory proposed in 1980 hypothesising that, 4,000,000,000 years ago, the northern hemisphere of Mars was struck by an object one-tenth to two-thirds the size of the Earth's Moon.



[FIGURE 14 \\\\ Geological Map of Mars. USGS. Modified for Colloquium 1.
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Fortezzo, C.M., Platz, T., Michael, G.G., and Hare, T.M., 2014, Geologic map of Mars:U.S. Geological Survey Scientific Investigations
Map 3292, scale 1:20,000,000, pamphlet 43 p.,http://dx.doi.org/10.3133/sim3292. 2014]

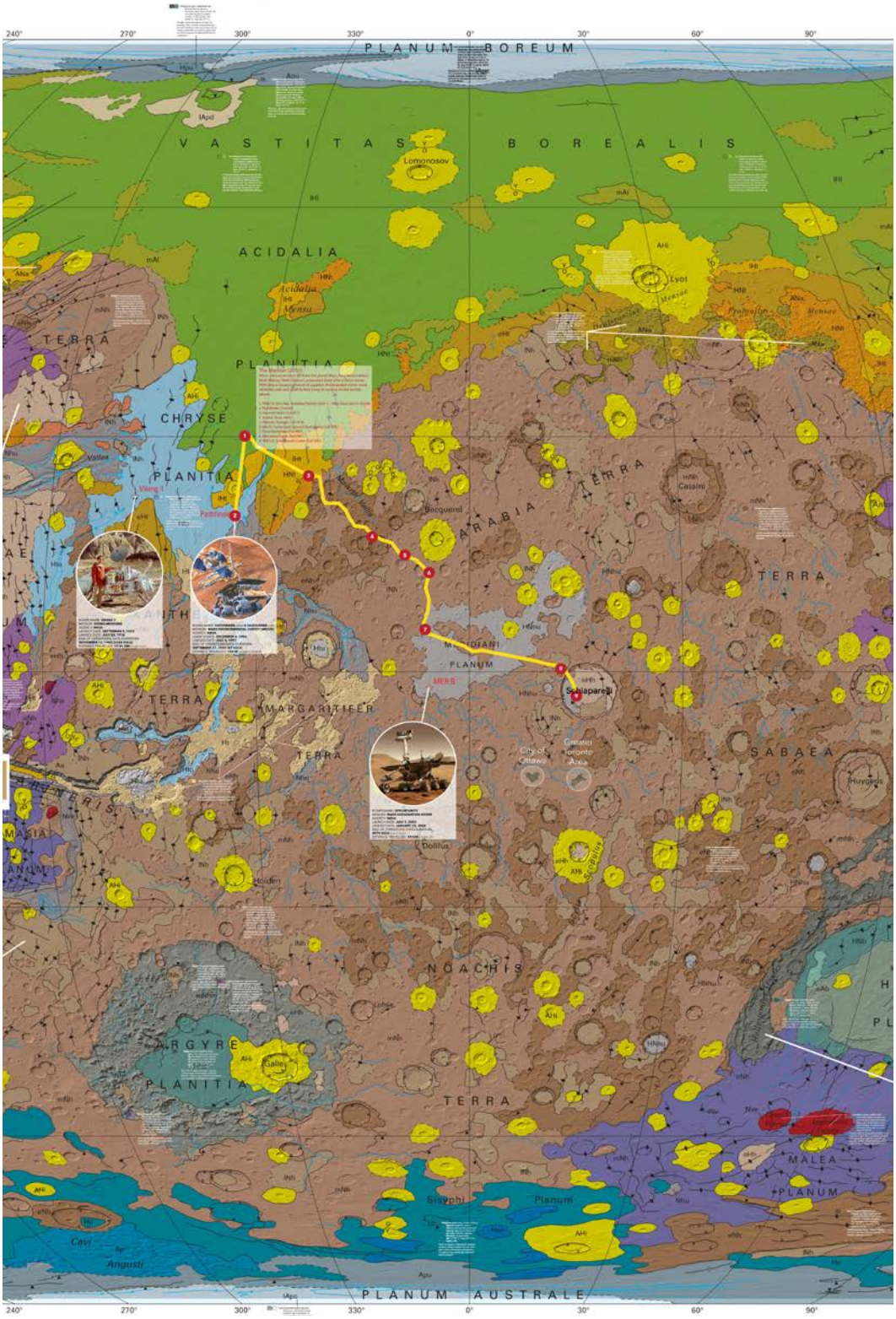
If correct, this would make the northern hemisphere of Mars the site of an impact crater 10,600 km by 8,500 km in size, or roughly the area of Europe, Asia, and Australia combined.[63] Mars is scarred by impact craters, over 43,000 with a diameter of 5 km or greater.[64] The largest of these craters is Hellas Planitia or Hellas Basin, an impact basin that spans more than 2000 kilometers in the southern hemisphere, a region that is heavily cratered and higher in average elevation than the northern hemisphere. This region is referred to as the "southern cratered highlands".[65] The depth of Hellas from its bottom to its inner rim is more than 4 kilometers. To better comprehend its scale, the depth of the Grand Canyon is roughly 1.6 kilometers and its span is almost half the size of Canada.[66]

Craters on Mars make excellent sites for future settlements. The natural shape of the impact crater creates predetermined sized cities, or states that would spread to fill the crater. The impact from another celestial object, a meteorite that struck the surface, would bring alien minerals, or elements to the planet. Extracting these alien resources could have desirable characteristics that would be beneficial for manufacturing. If a comet were to strike the surface, depending on the size and if any of the ice on the comet survived the entry into the thin Martian atmosphere, a crater formed from a comet strike could have water in it.

MARS

Major sites

Geological base map with sites of existing martian habitants (rovers and landers).
Potential sites for MARS COLONY 1



[FIGURE 15 \\\\ Geological Map of Mars. USGS. Modified for Colloquium 1.
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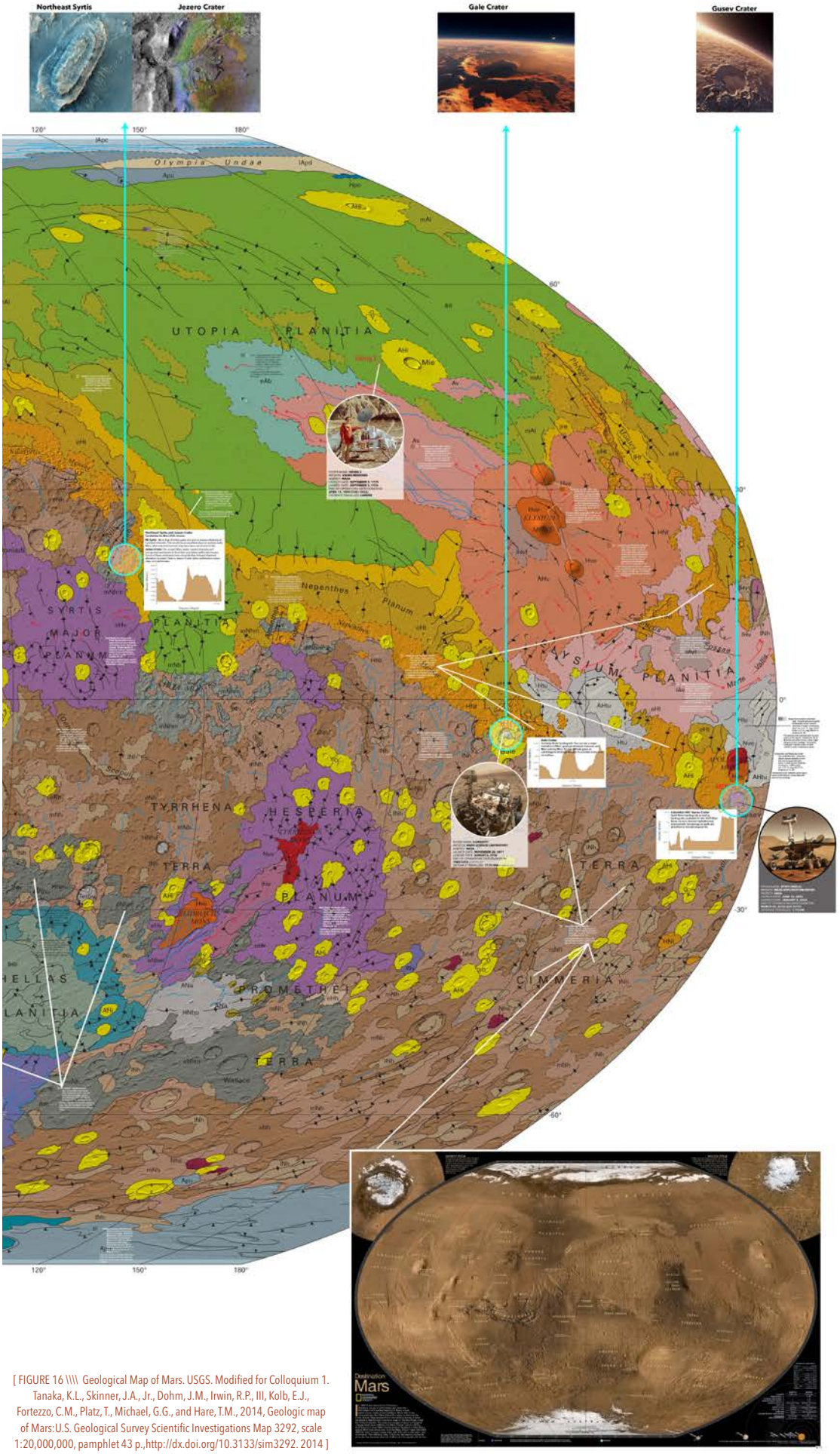
Craters create low points in the landscape, when water returns to the barren planet after an extensive terraforming effort, these craters could become lakes or oceans. The insides of the crater are naturally protected by their rim, acting like mountain range would on Earth to break strong winds. Craters however are not ideal because they are exposed to the dangers that travel through outer space. Mars' lack of magnetic shielding means that cosmic rays are absorbed by the planet and not bounced back into space, like they would be by Earth's magnetosphere. The magnetosphere of the Earth creates an invisible shield blocking cosmic rays from entering, but also keeps the atmosphere of the Earth from escaping into outer space. The lack of an atmosphere on Mars means that meteorites strike at almost full force, making their strikes equivalent to a nuclear bomb explosion if big enough.

Craters that could potentially be used as settlement sites. have many benefits; protection from winds/dust storms, settlements can be planned or grow naturally, like an organism, spreading out in ways necessary for survival. A planned city could place industrial processes outside the main city; domes above the city would protect the inhabitants from the lack of atmosphere, providing an enclosed environment where settlers would be able to live their day-to-day lives without having to wear space suits.



[FIGURE 16 \\\\ Geological Map of Mars. USGS. Modified for Colloquium 1. Tanaka, K.L., Skinner, J.A., Jr., Dohm, J.M., Irwin, R.P., III, Kolb, E.J., Fortezzo, C.M., Platz, T., Michael, G.G., and Hare, T.M., 2014, Geologic map of Mars:U.S. Geological Survey Scientific Investigations Map 3292, scale 1:20,000,000, pamphlet 43 p.,http://dx.doi.org/10.3133/sim3292. 2014]

Craters, created by foreign objects from outer space, offer potential mineral deposits for valuable raw materials to send back to Earth or use for manufacturing on Mars.

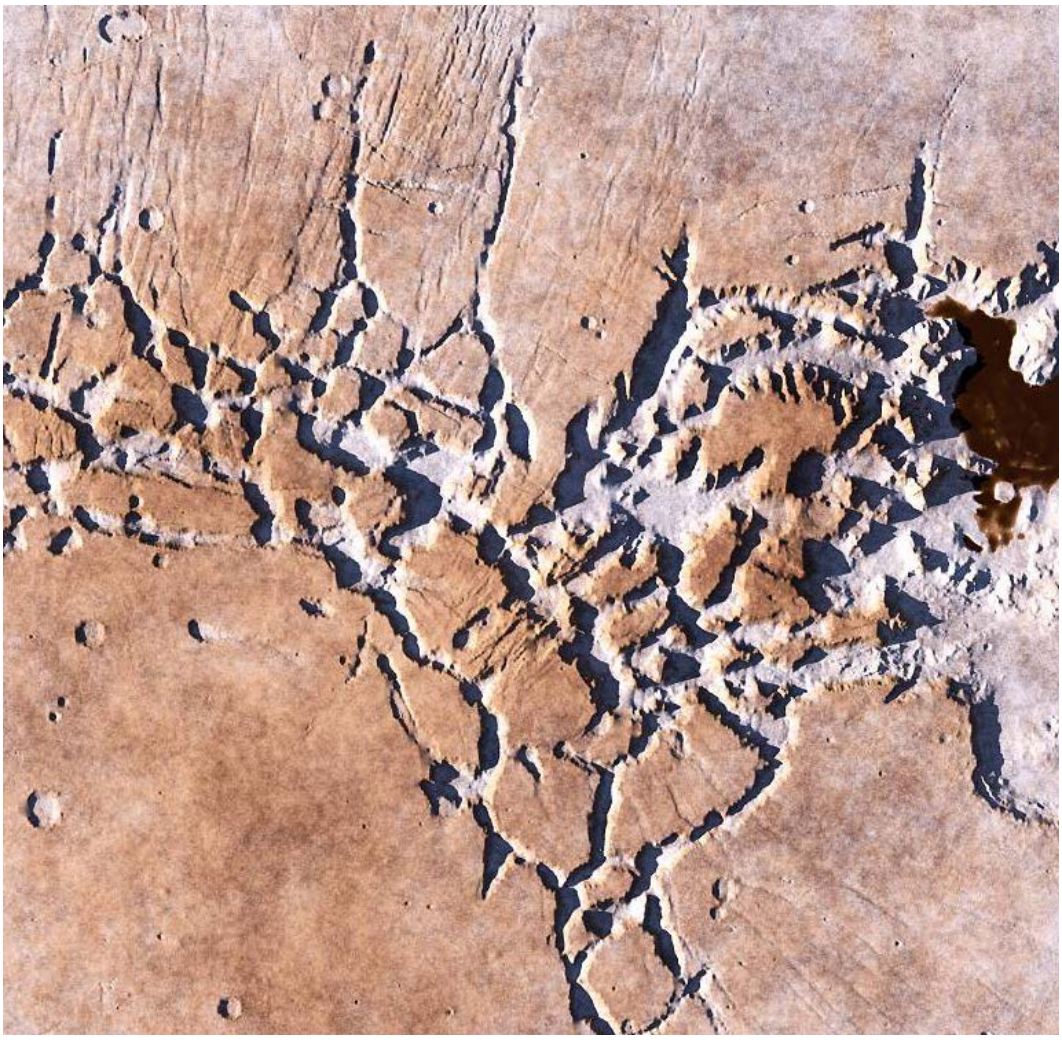
Other potential sites on Mars are underground caves that penetrate the surface through the sides of the great volcanoes in the Tharis region of Mars. Images from the Thermal Emission Imaging System (THEMIS) aboard NASA's Mars Odyssey orbiter have revealed seven possible cave entrances on the flanks of the volcano Arsia Mons. These caves are thought to be volcanic vents/lava flows from millions, or billions of years ago when the Tharsis Montes volcanoes were active.[67] The interiors of these caverns may be protected from micrometeoroids, UV radiation, solar flares and high energy particles that bombard the planet's surface on a regular basis.

The landscapes of Mars share similar characteristics to their counterparts on the Earth, however, the Martian landscapes dwarfs those on Earth, the volcanoes of Mars are known to be the largest in the solar system. The three Tharsis Montes are shield volcanoes centered near the equator in Mars's western hemisphere is a massive volcano province known as the Tharsis bulge. This massive, elevated structure is thousands of kilometers in diameter and covers up to 25% of the planet's surface. [68]

[FIGURE 17 \\\\ Olympus Mons. Artist Rendering. Kees Veenenbos.
Made from Digital elevation models of the Mars Orbiter Laser
Altimeter (MOLA). 2002]

Averaging 7–10 km above datum (Martian "sea" level), Tharsis contains the highest elevations on the planet and the largest known volcanoes in the Solar System. Three enormous volcanoes, Ascraeus Mons (18 km), Pavonis Mons (14 km), and Arsia Mons (20 km) are collectively known as the Tharsis Montes and sit aligned NE-SW along the crest of the bulge. The vast Alba Mons (6.8 km tall and 1,350 km wide) occupies the northern part of the region. The huge shield volcano Olympus Mons stands at 21 km tall, compared to Mt. Everest at only 8.8 km tall,[69] lies off the main bulge, at the western edge of the province. The extreme massiveness of Tharsis has placed tremendous stresses on the planet's lithosphere. As a result, immense extensional fractures (grabens and rift valleys) radiate outward from Tharsis, extending halfway around the planet.[70]

At the tops of the volcanoes are calderas, collapsed areas at the summit that were triggered by the emptying of the magma chamber beneath the volcano, sometimes as the result of a large explosive volcanic eruption.[71] Because the Tharsis Mons region is located at the equator, with Pavonis Mons sitting almost on top of it, plus its gargantuan height, the volcanos are an ideal location for an arrival point on the planet.



[FIGURE 18 \\\\ Noctis Labyrinthus.
Artist Rendering. Kees Veenenbos. Made from Digital elevation
models of the Mars Orbiter Laser Altimeter (MOLA). 2002]

In **"Journey of a Robotic Architect",** the caldera of Pavonis Mons is selected to house the Space Elevator Anchor, along side a new settlement to support the space elevator and be the new arrival hub for the planet. The space elevator will allow spaceships to dock with a space station at the top of elevator in space, beyond Mars' gravitational pull, and travel by space elevator car down to the surface.

The largest canyon system, Valles Marineris is 4,000 km in length, long enough to span one-fifth the circumference of Mars or the length of Europe. It has a depth of up to 7 km, by comparison, the Grand Canyon on Earth is only 446 km long and nearly 2 km deep.[72] Valles Marineris was formed due to the swelling of the Tharsis area, which caused the crust to collapse. In the massive canyons of Valles Marineris, a settlement could be proposed to be carved into the canyon wall itself, a 5 km vertical city protected by the Martian terrain with access to sunlight through cut outs in the cliff walls. This holds the benefit of the layers of rock offering ample natural protection from cosmic radiation. Solar panels on the cliff faces would generate electricity, and excavated material from tunneling could be processed for valuable raw materials and then used to manufacture building supplies.

[FIGURE 19 \\\\ Ius and Melas Chasma Valles Marineris.
Artist Rendering. Kees Veenenbos. Made from Digital elevation
models of the Mars Orbiter Laser Altimeter (MOLA). 2003]

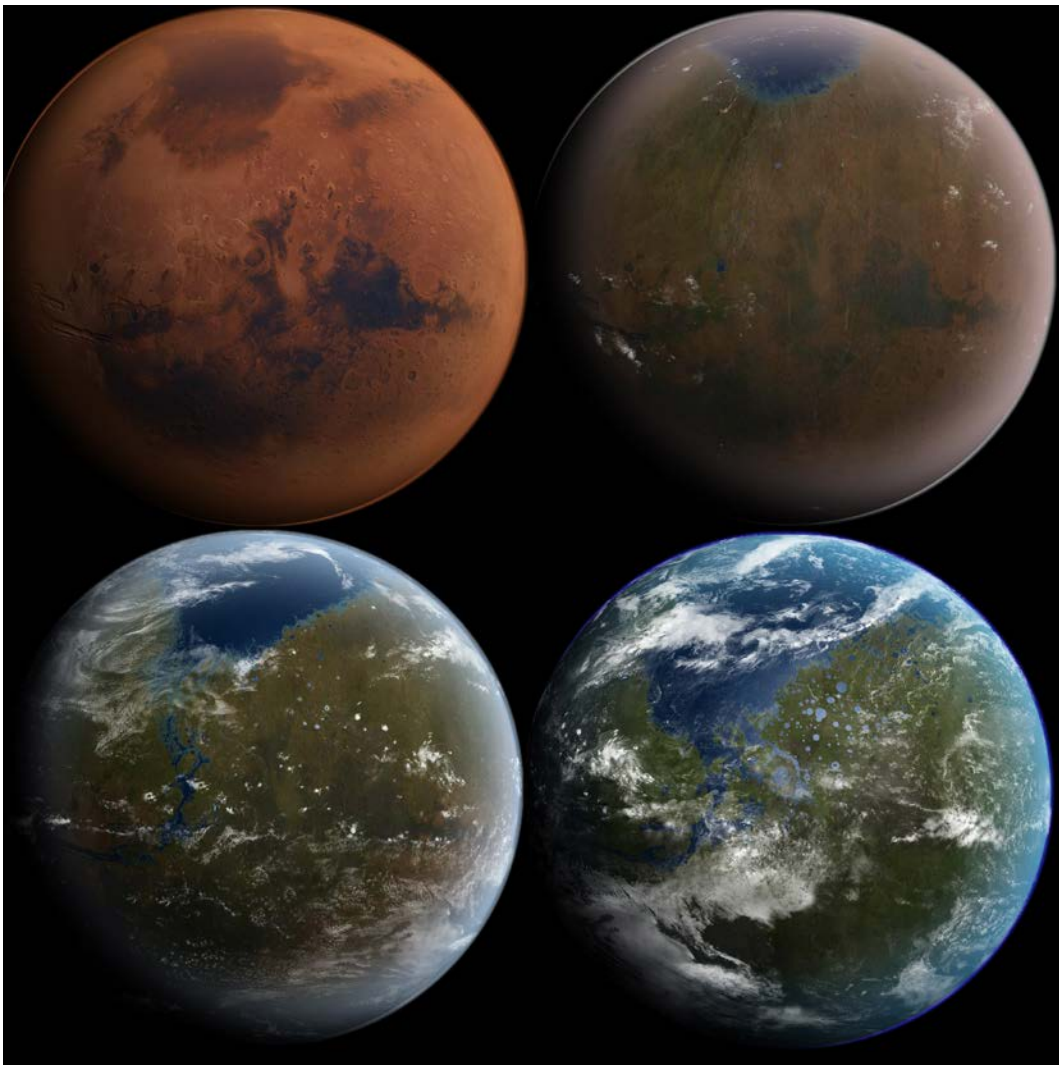
[FIGURE 20 \\\\ Farmers Wanted for Survival on Mars.
"Got a green thumb? This one's for you! In space, you can grow tomatoes, lettuce, peas, and radishes just like you would find in your summer garden. New ways of growing fresh food will be needed to keep brave explorers alive."
NASA/KSC. 2009]

INFRASTRUCTURE & TERRAFORMING; MAKE MARS BLUE AGAIN

\\\\ MARS, THE RED PLANET

Settling on Mars will be a large venture out into our solar system and the known universe. Getting people to Mars will require trillions of dollars, quadrillions of man hours and many years to establish a self-sufficient settlement that is independent from the Earth's leadership and diminishing resources. Some major pieces of infrastructure that would be essential to the long-term success of Mars would be establishing shelter, life support systems (water and air supply and recycling), farming and food production, power generation, and transportation links.

Initial settlements and shelters on Mars will be structures brought from the Earth, much like the lightweight modular structures that NASA is developing now. Astronauts train for long-duration deep space missions in the Human Exploration Research Analog (HERA) or at the Hawaii Space Exploration Analog and Simulation (HI-SEAS), both are self-contained environment that simulates a deep-space habitat. Both comprise of a two-story habitat with living quarters, workspaces, a hygiene module and a simulated airlock. Within the module, test subjects conduct operational tasks, complete payload objectives and live together for extended periods of time, simulating future missions in isolated environments.



[FIGURE 21 \\\\ Terraforming. Mars in transition. Daein Ballard. 2006]

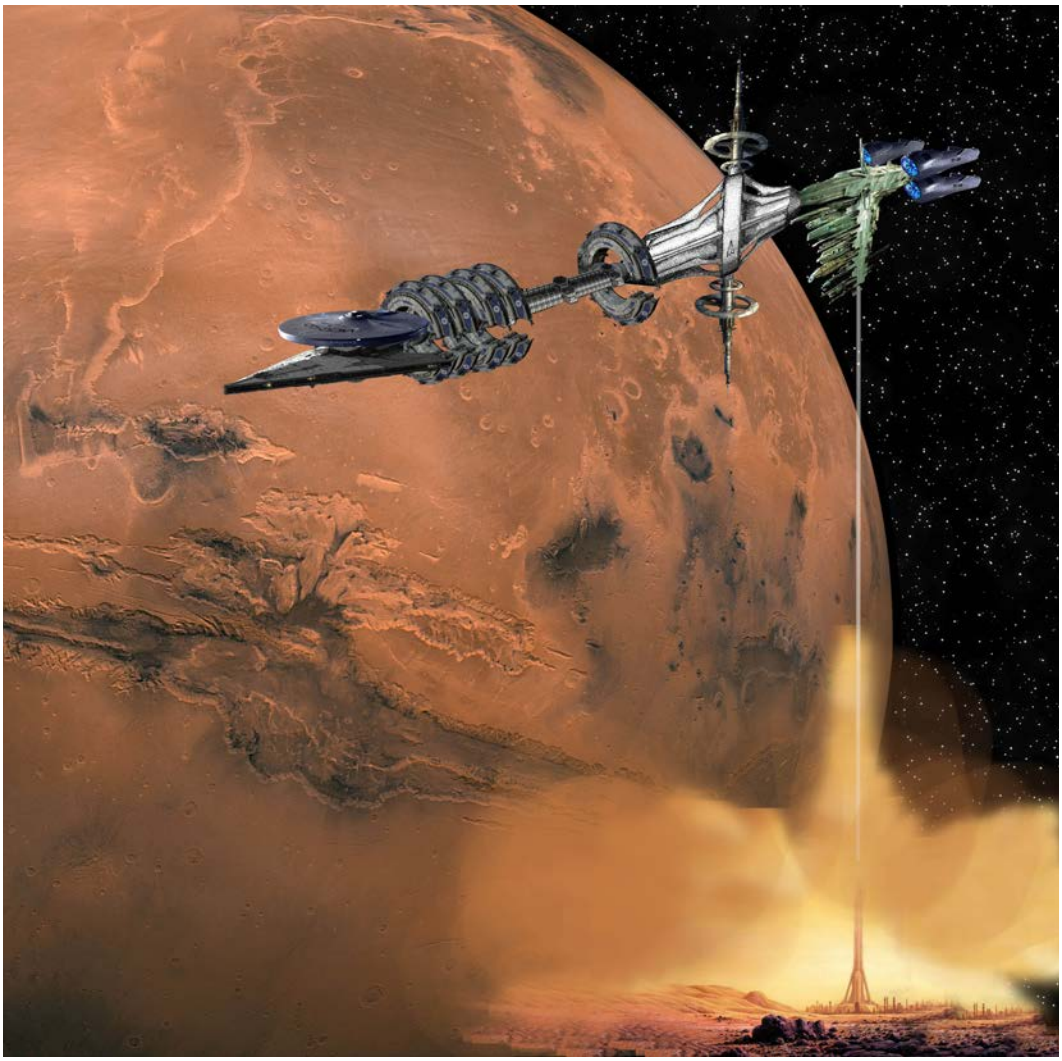
Astronauts recently used the facility to simulate ISS missions. This research provides valuable data in human factors, behavioral health and countermeasures to help further NASA's understanding on how to conduct deep space operations.[73] [74]

Power generation will be accomplished through solar and nuclear fusion power. Transportation links like navigable roads and high-speed trains between settlements will allow for the movement of settlers to move along the surface of the planet freely. Space ports and fuel production facilities will supply fuel for the vast fleet of SpaceX's BFR Starships ferrying people from the Earth. The biggest transportation project would be the space elevator, where rockets will be able to dock with a space station in areosynchronous orbit, then settlers will take an elevator down to the surface, saving rocket fuel needed to escape Mars' gravity. And the biggest infrastructure project would be the terraforming of Mars. The idea of a Space Elevator can be credited to several different people spread over the past century. In 1895, Russian scientist Konstantin Tsiolkovsky first proposed a tower into space, inspired by the Eiffel Tower. In 1959, Yuri Artsutanov, imagined a tensile structure, where something was being pulled away from the Earth, rather than built up, to escape Earth's gravity and get into space.

This idea used a satellite in geosynchronous orbit to send a tether down to the Earth. In 1966, four American scientists wrote an article about their "sky-hook" in the journal "Science". American Jerome Pearson independently 'discovered' the idea of a Space Elevator and, in 1975 published his concept of the "Orbital Tower". And in 1979, the concept spread to a larger audience with Arthur C. Clark's novel The Fountains of Paradise.[75]

A space elevator is a proposed type of planet-to-space transportation system. The main components of a space elevator is the cable (a tether), which is anchored to the surface (at a ground station) and extending into space (to a counter weight, like a captured asteroid). The design would permit vehicles (climbers or elevator cars) to travel along the cable from the planetary surface, directly into orbit, without the use of rockets.

The anchor of the elevator would best sit at the equator, rotating with the axis of the planet, giving the appearance of a stationary object in space. This means that objects attached to the cable would experience upward centrifugal force in the direction opposing the downward gravitational force. The higher up the cable the object is located, the less the gravitational pull of the planet, and the stronger the upward centrifugal force due to the rotation, so that more centrifugal force opposes less gravity.

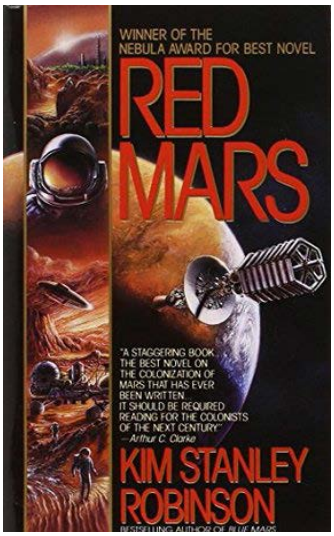


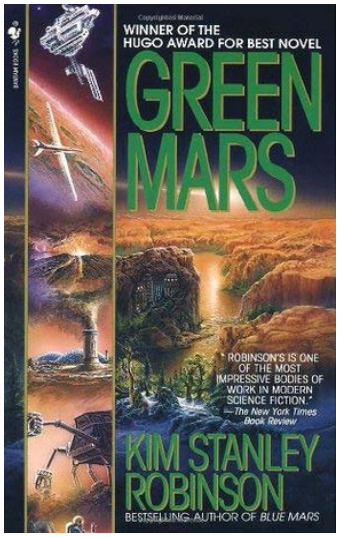
[FIGURE 22 \\\\ Starship Everything. Space Elevator Orbiting station made of other space craft from across science fiction. 2018]

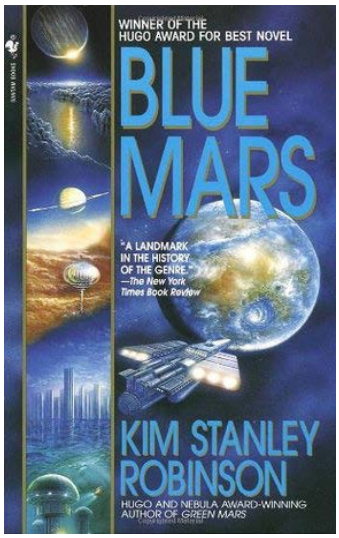
The centrifugal force and gravity are balanced at areosynchronous[76] equatorial orbit, past that the centrifugal force is stronger than gravity, causing objects attached to the cable to pull upward on it.[77]

The environment of Mars is not suitable for human life, it needs some persuading. Terraforming is the process to (especially in science fiction) transform (a planet) to resemble the earth, especially so that it can support human life.[78] At a NASA workshop, a paper titled "The Terraforming Timeline", presented an abstract plan for turning the Red Planet into something green and habitable. It states that terraforming Mars can be divided into two phases, the warming phase and the atmosphere phase. This warming phase could take ~100 years, relatively quick, where as the oxygenation phase is relatively difficult and would take 100,000 years or more, unless there is a technological breakthrough. In terms of architecture, terraforming is the equivalent to assembling a dome over an area to create a controlled environment. For large settlements on Mars, to feel free or resemble Earth, new domes will need to be developed, allowing people to freely roam around a settlement without the pressurized suits and personal breathing apparatuses.

In science fiction, Robinson's Mars trilogy, chronicles the colonization and terraforming of Mars over 200 years. The novels are titled according to the dominant color in the stage of terraforming achieved in each volume: Red Mars, when Mars is still in its natural state; Green Mars, when plants can grow in the atmosphere; and Blue Mars, when the atmospheric pressure and temperature have risen for seas and rivers to form.







[FIGURE 23 \\\\ Kim Stanley Robinson's Mars Trilogy. Red Mars (1992), Green Mars (1993), Blue Mars (1996)
Bantam Books]

[FIGURE 24 \\\\ Surveyors Wanted to Explore Mars and its Moons.
"Have you ever asked the question, what is out there? So have we! That curiosity leads us to explore new places like Mars and its moons, Phobos and Deimos. Just what lies beyond the next valley, canyon, crater, or hill is something we want to discover with rovers and with humans one day too."
NASA/KSC. 2009]

INHABIT VS COLONIZE

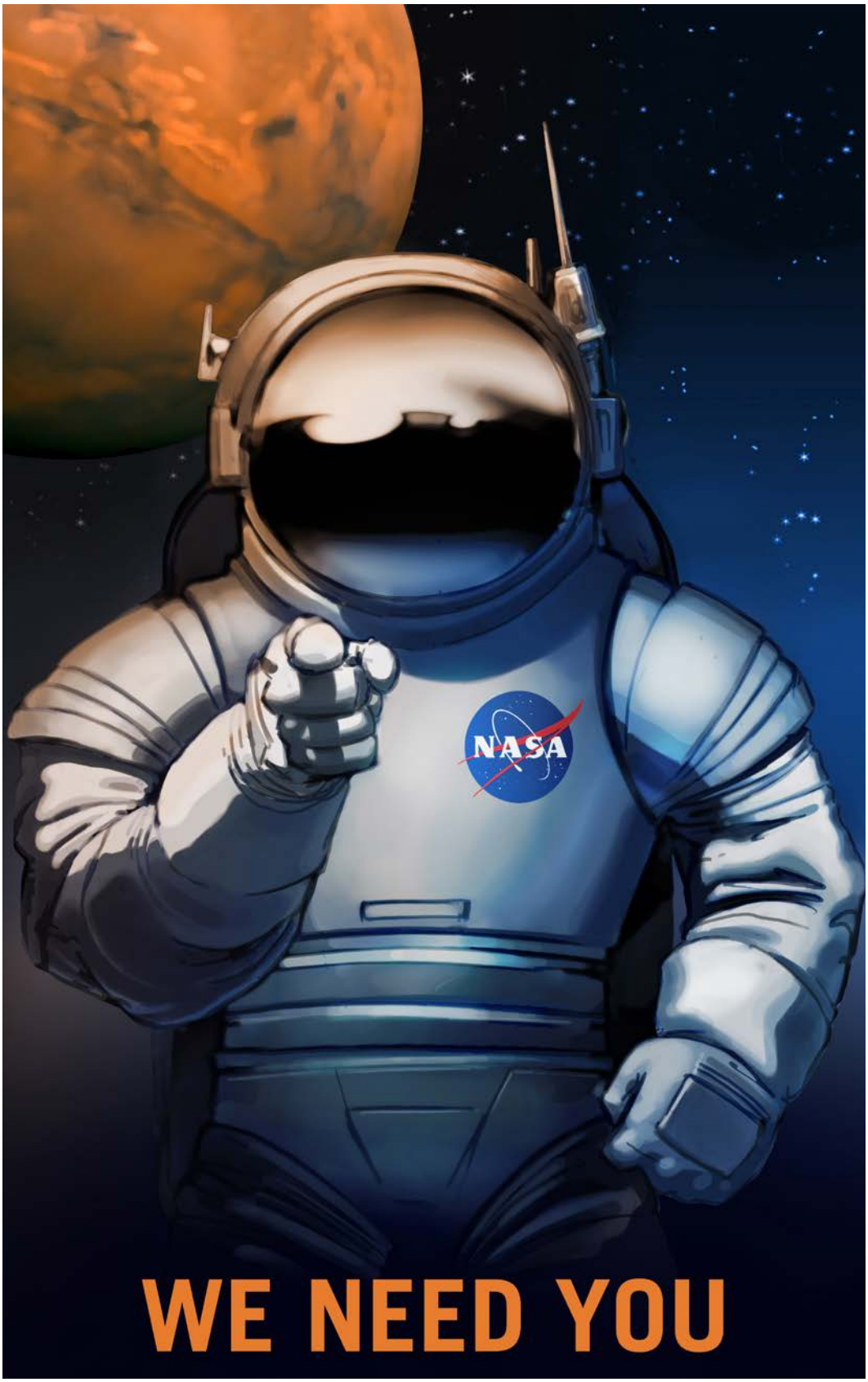
I wonder if creating a human settlement on Mars is a form of colonization? In the novel **"The Martian"** (Andy Weir, 2011), astronaut Mark Watney says "They say once you grow crops somewhere, you have officially colonized it. So, technically, I colonized Mars".[79] Of course, there is no intelligent advanced life on Mars that is being colonized in the traditional Earthly meaning of the word. Or soil that would be able to grow crops, but it is a planet that is being settled, through physical occupation, and later establishes a political governance. Is this a case where humans simply 'inhabit'- and perhaps consider what it is that we should do differently than in the past? Even if this is not raised as an issue by literature, I would like to raise the suggestions that we should learn from our past and a difference should be established from past colonizing efforts, towards multicultural habitat settlements. However, as there is no life on Mars, that we know of, my concern is the exploitation of Martian resources. In order to terraform the planet and make it suitable for human life, we must pollute the planet to warm it up and create and breathable atmosphere, the exact opposite of what needs to be done to the Earth to ensure its survival.

So, to ensure we do not turn Mars into the Earth 2.0 (in its present form), we must be careful about how we raise the temperature of the planet, too much change in too soon a timeline could result in unforeseen events that could be catastrophic to a settlement over time. As we carefully raise the surface temperature and establish an atmosphere, the extraction of natural mineral resources could be used for manufacturing on Mars and then sent back to the Earth as ready-made products or raw materials. Either way, how and at what rate we pull resources from Mars can be designed to be part of how the architecture on Mars is established. Settlements built/dug into the Martian surface will displace a lot of Martian rock that can be used for building materials. This could work vice versa, where a resource has been extracted, large areas of underground tunnels or open pits can be transformed into settlements. It is unforeseen how the first human landing on Mars will change the current policies regarding the exploration of space and occupancy of celestial bodies. In the 1967, United Nations Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, determined that no country may take claim to space or its inhabitants. Since the planet Mars offers a challenging environment and dangerous obstacles for humans to overcome, the laws and culture on the planet will most likely be very different from those on Earth. [80]

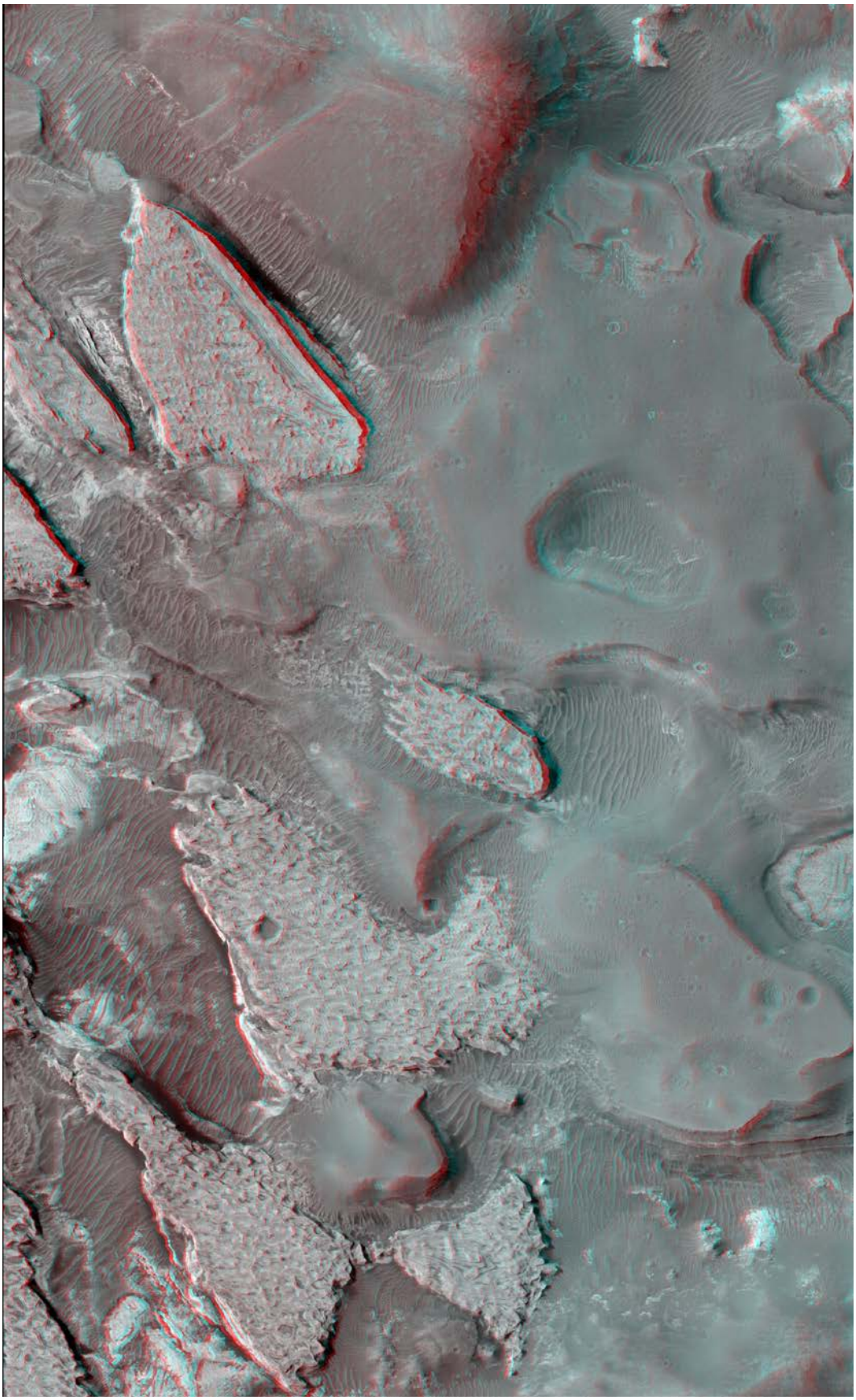
[FIGURE 25 \\\\ Teach on Mars and its Moons.
"Learning is out of this world! Learning can take you places you've never dreamed of, including Mars and its two moons, Phobos and Deimos. No matter where we live, we can always learn something new, especially with teacher-heroes who guide us on our path, daring us to dream and grow!"
NASA/KSC. 2009]

[FIGURE 26 \\\\ Technicians Wanted to Engineer our Future on Mars
"People with special talents will always be in demand for our Journey To Mars. Whether repairing an antenna in the extreme environment of Mars, or setting up an outpost on the moon Phobos, having the skills and desire to dare mighty things is all you need".
NASA/KSC. 2009]

[FIGURE 27 \\\\ Assembly Required to Build Our Future on Mars and its Moons
"Are you someone who can put things together, solving challenges to ensure survival? Dare to forge our future with space-age tools - build spaceships to carry us to Mars and back, and habitats to protect us while we're there."
NASA/KSC. 2009]



[FIGURE 28 \\\\ We Need You!
"We need many things for our Journey To Mars, but one key piece is YOU!"
NASA/KSC. 2009]



[Aram Chaos. HiRISE/ NASA/JPL/University of Arizona]

07

SCIENCE FICTION: REALITY AHEAD OF TIME

Science Fiction: Reality Ahead of Time.

SCIENCE FICTION: REALITY AHEAD OF TIME

References to science fiction and pop culture are ever present in both the science fiction and in the real world. With **David Bowie** and "**The Hitchhiker's Guide to the Galaxy"** being present throughout this thesis as well as given mentions to from companies like SpaceX, science fiction has been influencing the future for over century and will continue to do so; science fiction is reality ahead of time. Researchers are acknowledging the role of science fiction playing a part in triggering their interest in science and inspiring breakthroughs. This exchange goes in both directions – sometimes the technology appears first in science fiction, then becomes reality and other times the real technology comes first, and science fiction authors speculate about how it might be used, and how it might affect the human condition. Likewise, the accuracy of the technology portrayed spans a wide range – sometimes it is existing technology, sometimes it is a physically realistic portrayal of a far-out technology, and sometimes it is simply a plot device that looks scientific but has no basis in science.

Mars Society founder and aerospace engineer, Robert Zubrin has been pushing for manned missions and the settlement of Mars since the early 1990s. In his founding declaration of the Mars Society, Zubrin states "We're ready. Though Mars is distant, we are far better prepared today to send humans to the Red Planet than we were to travel to the Moon at the commencement of the space age. Given the will, we could have our first crews on Mars within a decade".[81] Zubrin's passion, like most aerospace engineers and space pioneers, stems from science fiction. In an interview with Michio Kaku, he said that he was mesmerised by von Braun's idea of how a mission of ten spaceship, assembled in orbit, could take a crew of seventy astronauts to Mars.

In 1897, H.G. Wells wrote **"The War of the Worlds"**, Martians use tripod-like mechanical suits to conquer the Earth. In 1894, a French astronomer observed a 'strange light' on Mars and published his findings in the scientific journal Nature on the second of August that year. Wells used this observation to open the novel, imagining these lights to be Martian cylinders launching toward the Earth.[82]

In Olaf Stapledon's 1937 novel, **"Star Maker"**, the main character unexplainably has an out of body experience and travels through time and space as pure consciousness. On his travels from star system to star system, he visits advanced alien civilizations. Witnessing their rise to greatness as they welcome peace and prosperity while others fall to ruin, destroyed by bitterness, conflict, and war. The Architect in **"Journey of a Robotic Architect"**, experiences the same out of body adventure, taking a smaller step into space and time, traveling to Mars where he is needed to assist humanity in building a Martian settlement. The parallels in the narratives are common themes throughout many science fictions, where a character looks out of their home and far into the stars to look for new worlds to explore.[83]

Jules Verne's science-fiction literature was "prophet" in relations to scientific progress, with many of his novels involving elements of technology that were fantasy for his day but later became reality.[84] As with science fiction, Verne himself flatly denied that he was a futuristic prophet, saying that any connection between scientific developments and his work was "mere coincidence" and attributing his scientific accuracy to his extensive research: "even before I began writing stories, I always took numerous notes out of every book, newspaper, magazine, or scientific report that I came across".[85]

One of the most important pieces of literature regarding space travel in science fiction is Verne's 1865 novel "**From the Earth to the Moon** (In French: **De la terre à la lune)"**. The novel tells the incredible journey of travelling to the Moon using a space gun, a really big cannon, used to shoot a projectile into space. This projectile could carry 3 people, including food & water, oxygen and other crucial cargo. Verne even included some basic calculations on the requirements for the cannon, which appeared to be surprisingly accurate. As it can be seen from the picture below, the projectile even resembles a modern space shuttle, illustrating how far science fiction evolved since the beginning. Or was the space shuttle designed after Verne's ship?

The importance of this novel in science fiction is that it paved the way for other writers to imagine space travel, a story that has been adapted many times in all kinds of ways. In 1880 The "Pall Mall Gazette" described Verne's Columbiad as a 'space-ship' - the first recorded use of this term in history. The novel (along with Wells' **"The First Men in the Moon"**) inspired the first science fiction film, **"A Trip to the Moon"**, made in 1902 by Georges Méliès. Science fiction builds on itself, often referencing past works directly or indirectly in newer works. Just like science reality, technology evolves by building on itself. This thesis attempts to build on both science fiction and science reality.

Given the sheer amount of sci-fi works that have appeared in the 20th century, it would take forever to describe how space travel has evolved in recent literature. It's enough to say that the 20th century can be described as the century of science and technology, which is obvious in the works of sci-fi as well. Space travel in recent novels incorporates the current understanding of the physics of space-time and quantum mechanics.[86] Even today, however, some of the early science fiction stories still remind us that even the final frontier is not the limit to the human imagination.

William Gibson's **"Neuromancer"** (1984), is a major influencer to many science fiction topics and terms that are commonly used today throughout science fiction. It was also credited with the idea of the Internet. Its cultural influences are credited with creating/legitimizing the cyberpunk sub-genre of science fiction. The novel has had significant linguistic influence, popularizing such terms as cyberspace and ICE (Intrusion Countermeasures Electronics) or cyber security. Gibson coined the term "cyberspace" in his short story "Burning Chrome", published in 1982 by Omni magazine, but it was through its use in **Neuromancer** that it gained recognition to become the term for the World Wide Web during the 1990s. The portion of **Neuromancer** usually cited in this respect is:

“

THE MATRIX HAS ITS ROOTS IN PRIMITIVE ARCADE GAMES... CYBERSPACE. A CONSENSUAL HALLUCINATION EXPERIENCED DAILY BY BILLIONS OF LEGITIMATE OPERATORS, IN EVERY NATION, BY CHILDREN BEING TAUGHT MATHEMATICAL CONCEPTS... A GRAPHIC REPRESENTATION OF DATA ABSTRACTED FROM BANKS OF EVERY COMPUTER IN THE HUMAN SYSTEM. UNTHINKABLE COMPLEXITY. LINES OF LIGHT RANGED IN THE NON-SPACE OF THE MIND, CLUSTERS AND CONSTELLATIONS OF DATA. LIKE CITY LIGHTS, RECEDING.

- William Gibson, Neuromancer 1984 [87]

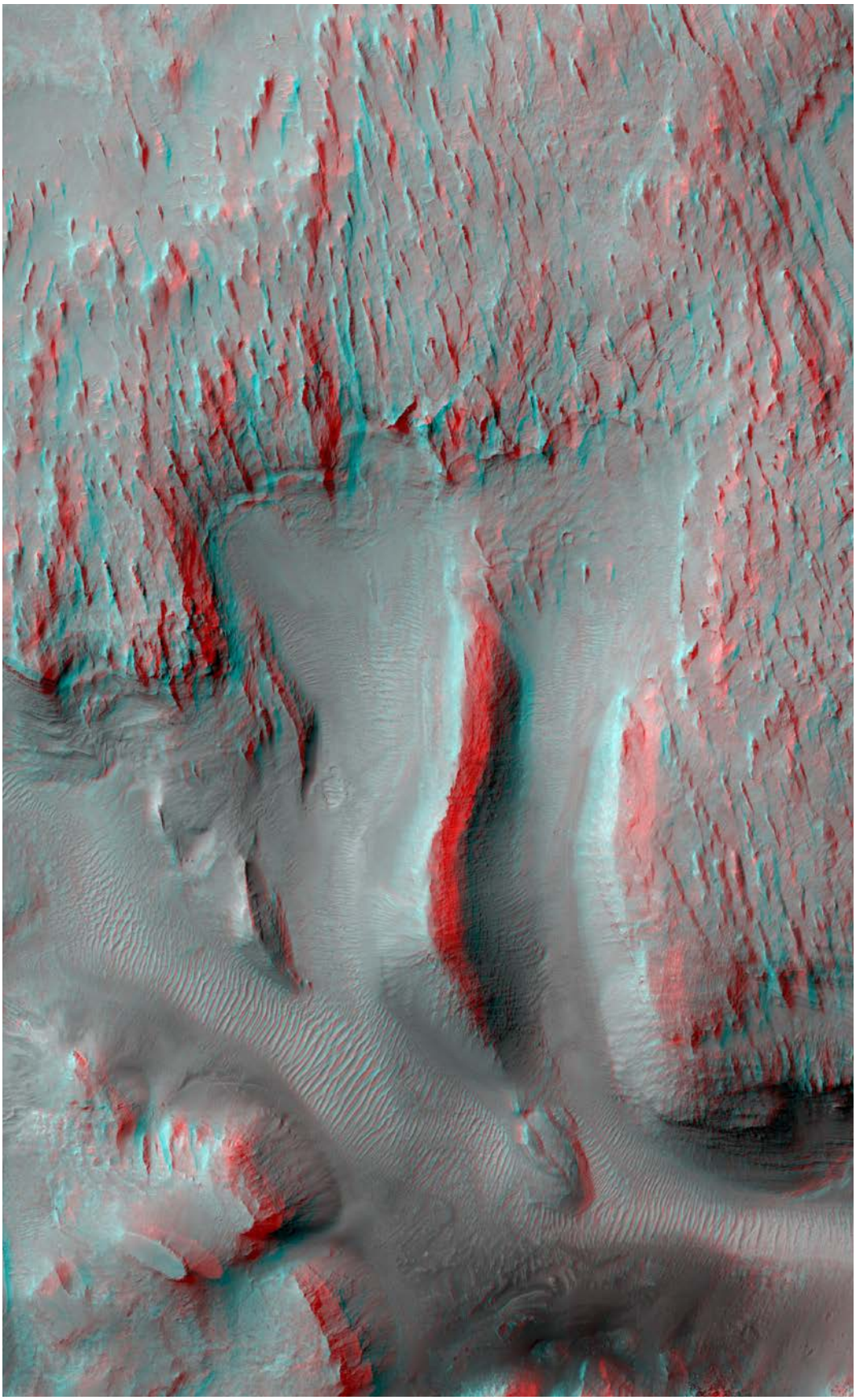
”

The 1999 film, **"The Matrix"** by The Wachowskis, draws from **Neuromancer** in regards to both the name and usage of the term "matrix". After watching **The Matrix**, Gibson commented that the way that the film's creators had drawn from existing cyberpunk works was 'exactly the kind of creative cultural osmosis' he had relied upon in his own writing.[88]

This thesis has influences from many great works of literature. Most notably Kim Stanely Robinson's **Mars Trilogy**. The novels chronicle the settlement and terraforming of Mars through the personal and detailed accounts of a vast company of characters ranging from the original explorers, The First Hundred, to their descendants and others across almost two centuries. The story is a utopian approach to Mars, with the focus on egalitarian[89] democratic, sociological, and scientific advances made on Mars, while the Earth suffers from overpopulation and ecological disaster. [90] [91] [92]

Science fiction literature takes influence from its predecessors, building on past plots, technologies, ideas, and events that's are happening in reality to make new connections and constructs storylines for the future.[93]

Note\\ There is an extensive list of science fiction literature and movies at the end of this thesis in Appendix C.

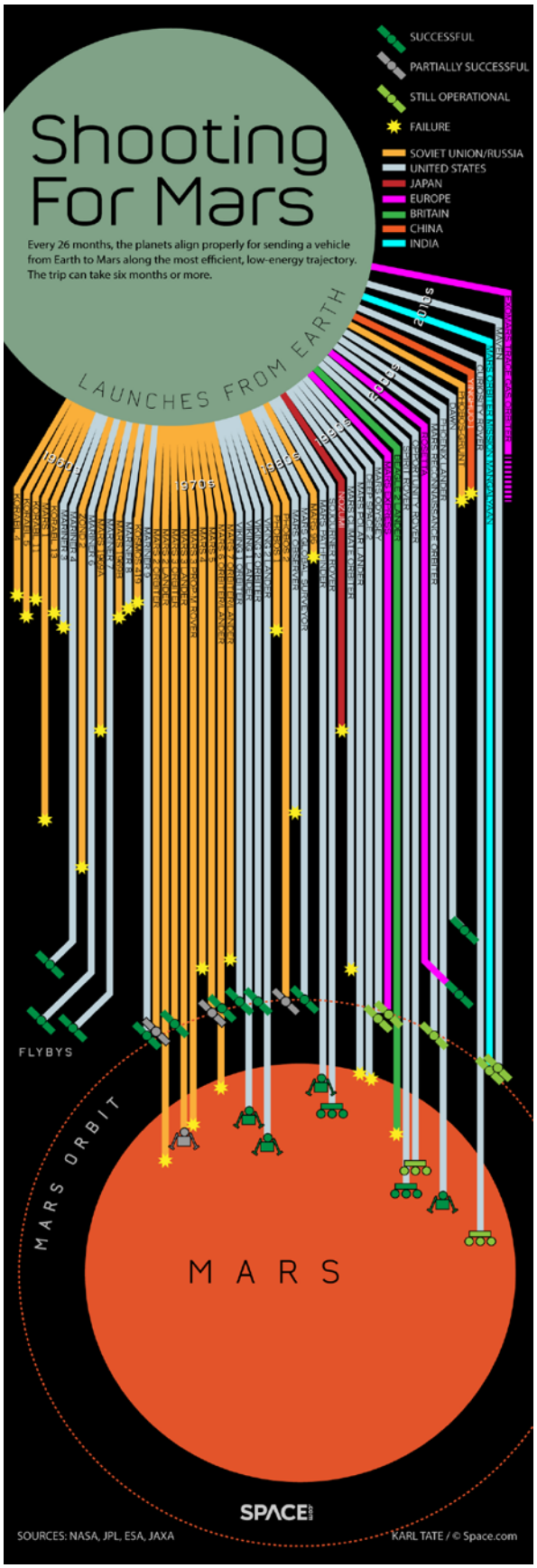


[Gale Crater. HiRISE/ NASA/JPL/University of Arizona]

08

RISE OF THE MACHINES

Rise of the Machines



[FIGURE 29 \\\\ Shooting for Mars. Objects we have sent to Mars. Karl Tate Space.com. 2016.]

RISE OF THE MACHINES

Robots have been assisting humanity since prehistoric times, mythological folklore from ancient Greece where legends of talking bronze and clay statues coming to life were a regular occurrence in the works of classical authors such as Homer and Plato. Robots are common aspects of science fiction and pop culture today. In Mary Shelley's **"Frankenstein"** (1818), Doctor Frankenstein creates his monster through the combination of chemistry and alchemy, developing a secret technique to impart life to non-living matter. The monster learns to read and speak, becoming an intelligent being. Being a creation of man, is the Frankenstein monster a machine with artificial intelligence? Or is it human?

Artificial intelligence (A.I.) is the next step in the evolution of robots for their integration into everyday life. With A.I., tasks can be completed with less input/instruction from humans. This means that robot will become self-sufficient to run themselves, becoming a background system in the daily lives of people. However, with advances in robotics, rules will have to be put in place so that they are not taken advantage of for the better of one person over another. Isaac Asimov wrote the Three Laws of Robotics in 1942 for his short story **"Runarounds"** and was later integrated into his **"I, Robot"** Collection in 1950.

The Three Laws [94], quoted from the "Handbook of Robotics, 56th Edition, 2058 A.D.", in **"Runarounds"** are:

***First Law** – A robot may not injure a human being or, through inaction, allow a human being to come to harm.*

***Second Law** – A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.*

***Third Law** – A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.*

The three laws form an organizing principle and unifying theme and continuity in all of Asimov's robotic-based fiction. The Laws are incorporated into robots and cannot be bypassed, being intended as a safety feature. Many of Asimov's robot-focused stories involve robots behaving in unusual and counter-intuitive ways as an unintended consequence of how the robot applies the Three Laws to the situation in which it finds itself. Asimov himself made slight modifications to the first three to further develop how robots would interact with humans and each other. In later fiction where robots had taken responsibility for government of whole planets and human civilizations, Asimov added a fourth, or zeroth law, to precede the others:

***Zero Law** - A robot may not harm humanity, or, by inaction, allow humanity to come to harm.*

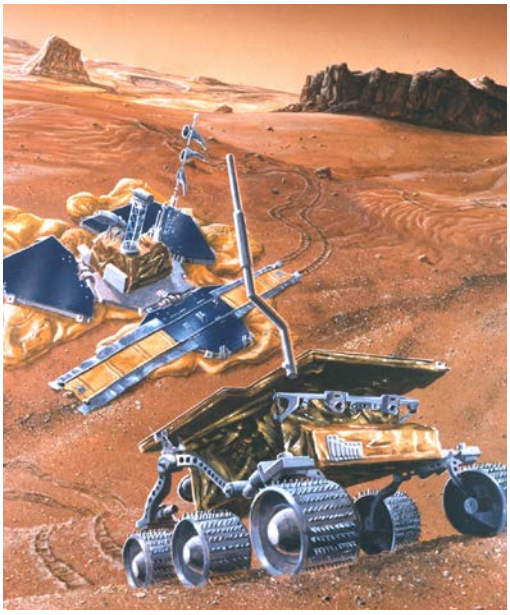
The Three Laws, and the zeroth, have been seen in many science fictions and are referred to in many other literary words and films, and have impacted thought on ethics of artificial intelligence as well.

A.I. can be helpful when used correctly, and if it doesn't realize it is more intelligent than its creators. But when they do, and they over power humanity, we get situations like Skynet from **Terminator**, the machines from **The Matrix**, and HAL 9000 from **2001: A Space Odyssey**. If humanity will be sending machines to Mars, we will need to make sure they will not turn on us and create a planet of robots. All joking aside, robots or drones will be key in settling Mars for humanity because the human body is still too weak to survive in space. Robots of today will not become the next apocalyptic raising machines but applying the Three Laws of Robotics to future A.I. will be key.

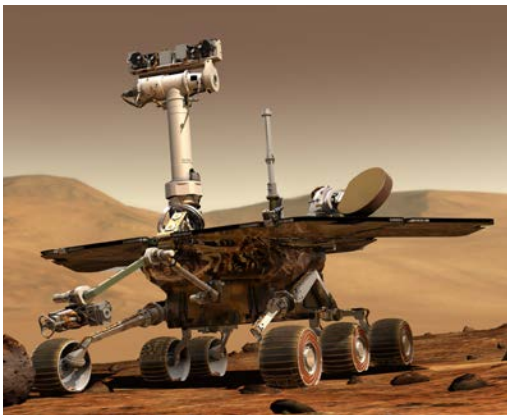
The Martian rovers of Spirit (Mars Exploration Rover – A landed January 4, 2004, mission declared 25 May 2011), Opportunity (Mars Exploration Rover – B landed January 25, 2004, mission declared February 13, 2019) and Curiosity (landed August 6, 2012) have all exceeded their original mission on Mars. They have been and continue to be the eyes and ears on Mars, collecting important information on the Martian climate, geology, and analysis of environmental conditions that could be favourable for microbial life, including investigation of the role of water; and planetary habitability studies in preparation for human exploration.[95]

The mission extension and continuous service of the Mars rovers and landers have been a testament to their engineering and key to the longevity of exploration on Mars. In "Journey of a Robotic Architect", the ending of the narrative suggests that, having completed the mission and still operational, the Architect can continue to work past his mission plan. Given that architecture regards human experience and understanding, artificial intelligence has limited awareness into the nature and tendencies of human experience, a human element is crucial because leaving design to machines alone would create an unlivable built environment. The settlements designed by the AI in the thesis narrative follow the ideas of the Garden City.

[Viking 1 & 2. Viking Missions. Landed 1976. NASA/JPL-Caltech]



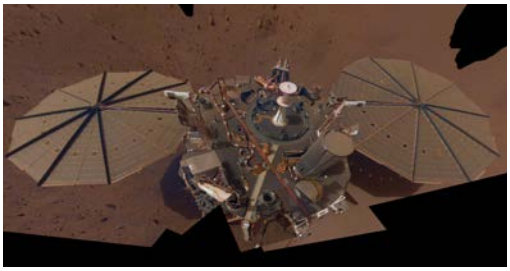
[Pathfinder and Sojourner. Mars Environmental Survey. Landed 1997. NASA/JPL-Caltech]



[Spirit and Opportunity. Mars Exploration Rover A & B. Landed 2004. NASA/JPL-Caltech]

[Pheonix Lander. Mars Scout Program. Landed 2008. NASA/JPL-Caltech]

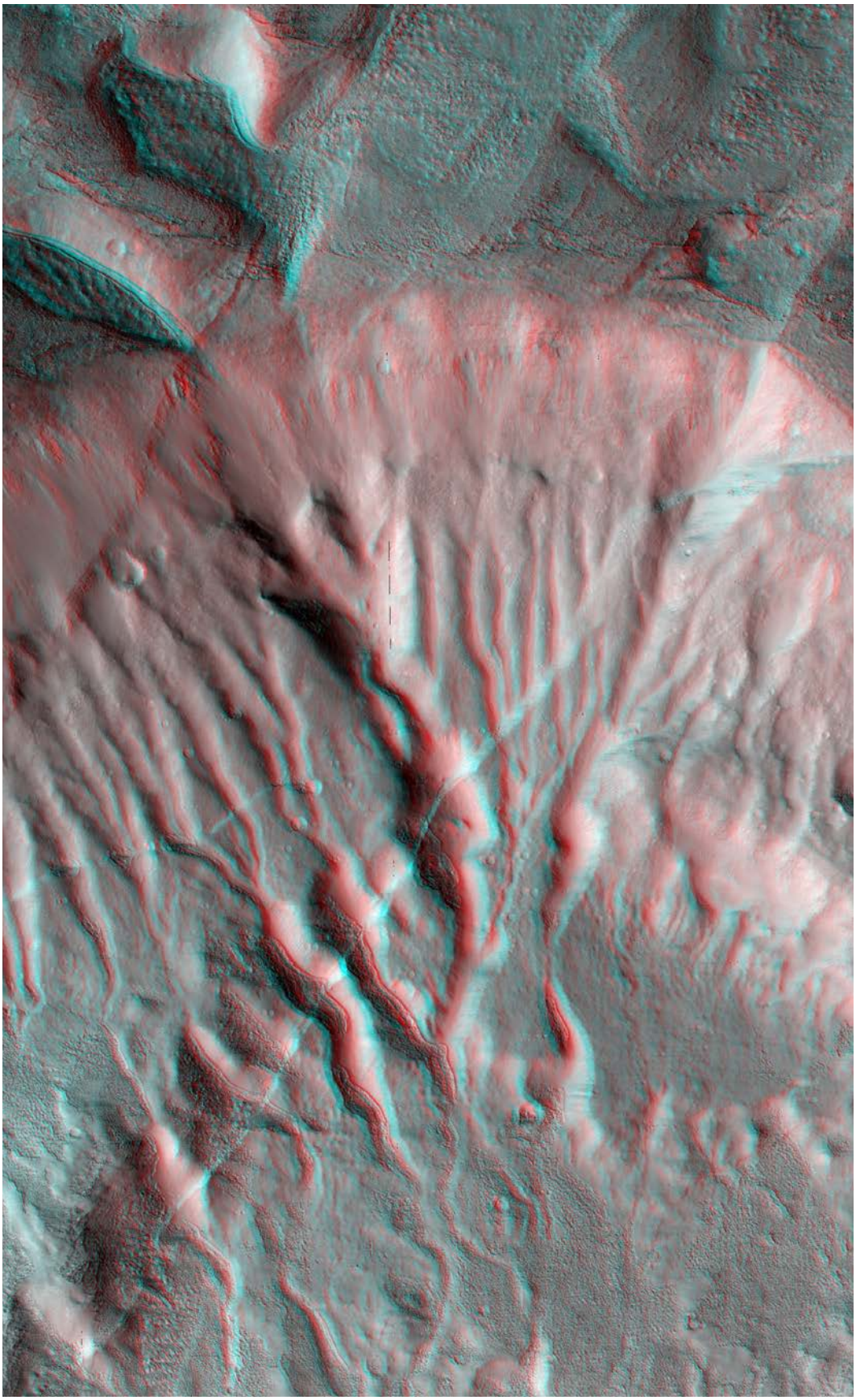
[Curiosity. Mars Science Laboratory. Landed 2012. NASA/JPL-Caltech]



[InSight. Interior Exploration using Seismic Investigations, Geodesy and Heat Transport. Landed 2018. NASA/JPL-Caltech]

[FIGURE 30 \\\\ Habitants of Mars. Rovers and Landers. NASA/JPL-Caltech]

Known to be highly organised, it has been criticized to be that Garden cities created isolated communities to categorize all like things together, an environment where Artificial intelligence and robots would thrive. Artificial intelligence is the gathering and use of data to solve a problem. If an artificial intelligent architecture program was to design a new settlement on Mars with no real time data specific to that local Mars settlement, it would base its design on cities on Earth. The garden city being highly organised, the logical choice would be that. It does not understand the human experience in the design. After the collection of data, the A.I. program can calculate population growth, prioritize projects, categorize streets according to usage, alter the urban fabric as needed, predict future settlements based on previous data and so on. Once the collected data is inserted as parameters, the design brief of the settlement applied to the program, the A.I. will suggest a range of solutions which fulfill these criteria. Once an altered or new settlement is built and lived in, the collection of new data will be used to form the next settlement. The AI would be integrated throughout the city, collecting data in real time and looking for patterns in movements and usage. Today, the ever-growing connection of people via technology through the web is enabling a more open and transparent look into everyone's life. By knowing what we like, our social media, what we buy or where we go, our smartphones, tablets and computers know us better than we know ourselves.[96 97 98]



[Tempe Terra. HiRISE/ NASA/JPL/University of Arizona]

09

SPACE ARCHITECTURE

SPACE ARCHITECTURE

Space architecture is a place of function with very little form. The architectural approach to spacecraft design addresses the total built environment. It is mainly based on the field of engineering (especially aerospace engineering), but also involves diverse disciplines such as physiology, psychology, and sociology. Like architecture on Earth, architecture is to go beyond the component elements and systems and gain a broad understanding of the issues that affect design success.

Vitruvius said that all buildings should have three things: strength, utility, and beauty.[99] The tremendous challenge of living in space has led to habitat design based largely on functional necessity with little or no applied ornament. In this logic, space architecture as we know it shares the form follows function principle with modern architecture. Walter Gropius wrote: " 'Beauty' is based on the perfect mastery of all the scientific, technological and formal prerequisites of the task... The approach of Functionalism means to design the objects organically on the basis of their own contemporary postulates, without any romantic embellishment or jesting."[100]

The modules that make up the International Space Station are scientific experiment chambers, designed by scientists and engineers for performing tasks in space. Yet, they compromise livability and healthy environments. With design support from architects, space architecture should become places that serve more than the survival of the user, but a place where the user can live comfortably.

The idea of exploring and settling on Mars has been explored in science fiction for over a century. The earliest depiction of Mars in fiction involved a planet with canals, vegetation and Martians – owing to the observations of astronomers like Giovanni Schiaparelli and Percival Lowell.[101] However, when the Mariner 4 (1964) mission proved the true conditions of Mars, the accounts in science fiction shifted to human colonization of the planet. Ray Bradbury's series of short stories in "The Martian Chronicles" (1950) best illustrates this change, beginning with a Martian civilization encountering human explorers, which quickly transitions to stories that deal with human settlements on the planet, the genocide of the Martians, and Earth eventually experiencing nuclear war. [102]

This thesis explores Mars as the next step for human exploration into the stars. In the narrative, the construction rovers on Mars are in the process of building settlements on the planet in strategic locations, the space elevator sitting at the top of Pavonis Mons is key because it is the highest point on the equator, an ideal location for connecting an object in space to a fixed point on the surface. At the end of the narrative, the architect decides to travel across the planet in search of other locations that could be candidates for future settlements, examining their benefits and drawbacks.

Picking a site on Mars would be like how new settlements on Earth would have been chosen in the ancient world. In "The Idea of a Town", Joseph Rykwert extensively discusses how ancient societies like the Greek and Roman Empires would pick new sites for their cities.[103] We can look to our history to be inspired for our future when building on Mars.

The reason to settle on Mars is apparent in the challenges and the opportunities it presents. Crossing vast oceans, climbing the highest mountains, and visiting the most extreme environments inspire the next generation and lead to unexpected scientific and economic discoveries. Traveling to Mars and installing a new outpost for humanity could push the limits of technology, the human psyche, design, and potentially teach us how to live better on Earth.

SITES AND CRITERIA

Early Martian settlements in craters would be more organic in their formation, as buildings are needed, they can be built in open spaces. In Kevin Lynch's **"Good City Form"**, one of his normative theories states that the city is an organism, a notion that came from the rise of biology studies on Earth in the 18th and 19th centuries. It was part of a reaction to the stress of industrialization, massive cities and great leaps in technology. Organisms are autonomous individuals with definite boundary and size. It reorganizes itself as it changes rather than expand or swell, or add parts, and the change is a radical one. External boundaries are sharp, internal parts are indistinguishable and not easy to divide. The parts work together and influence each other. Form and function are inseparably linked and the whole system is complex. The organism is dynamic, self healing, self regulating, and self organizing.[104]

To determine a site on Earth, Joseph Rykwert, "The Idea of a Town", discusses the ancient methods used by the Greeks and Romans for city finding and planning. Quoting politics, Aristotle recommended that the site for a new city be sloped eastward, with winds that blow from where the sun rises. Aristotle also recommends that the site should be well positioned for civil and military activities.

Vitruvius adds that, the site must be healthy first, then well situated. It should be high, not in a climate where the air is saturated in moisture and produces mist or frost. The climate can't be too hot or cold. No marshes in the area. A new site will be unhealthy if it sits exposed to the south and west along the coast. Vitruvius also warns of having streets running in the same direction as the wind, the streets will be swept away acting like a funnel. Vitruvius suggested a 16-ray arrangement where all main streets meet the strongest winds at an oblique angle.

A common theme of picking a new site for a city is that it must be healthy. Healthy is not really described or defined but speculated that they mean it must have access to water for drinking (spring) and shipping (river or sea), good soil for crops, animals for livestock and food, forests for lumber, minerals for tools and weapons and stones for building.

The criteria for an ideal site or settlement on Earth does not work for Mars. Mars is a desert planet with little to no water and no “healthy” sites. An ideal settlement site on mars would have access to water (whatever little there might be), natural landforms for shelter, open areas for landing spacecraft, a location near the equator where seasons shifts are not extreme and sunlight is maximized, not in high elevation areas due to decreased time for atmospheric braking, avoid steep slopes, avoid rocky terrain, and avoid thick layers of dust. Orbiting satellites gather information that is then used to determine the geology of the site, determining if a site is suitable for a settlement.

DETERMINING AN URBAN PLAN

There are no formulas for city planning and no defined cookie cutter ways for planning new settlements on Mars. All examples of the Earth were designed for it, utilising its natural resources where possible. Mars is a deserted wasteland and all its resources are mostly underground. A blank slate provides a chance to create elements of good urbanism from the start. There aren't too many places to start new cities on Earth, except in remote and deserted places. The challenges of lethal surroundings and the freedom of lower gravity changes the rules of conventional design, but by redefining how we interact with nature and ourselves, space settlements offer a broader chance to remake urbanism itself, and by extension, public spaces and the publics who use them—the implications of which could play out both on Mars, and on Earth.

Space architect Brent Sherwood wrote, "living far away from Earth in confined, artificial environments will challenge psychological health in brand new ways. That's why, if we choose to accept the serious challenges and risks that come with off-world living, it's important for architects and designers to start thinking about how to make spaceships and habitats not just survivable, but livable."

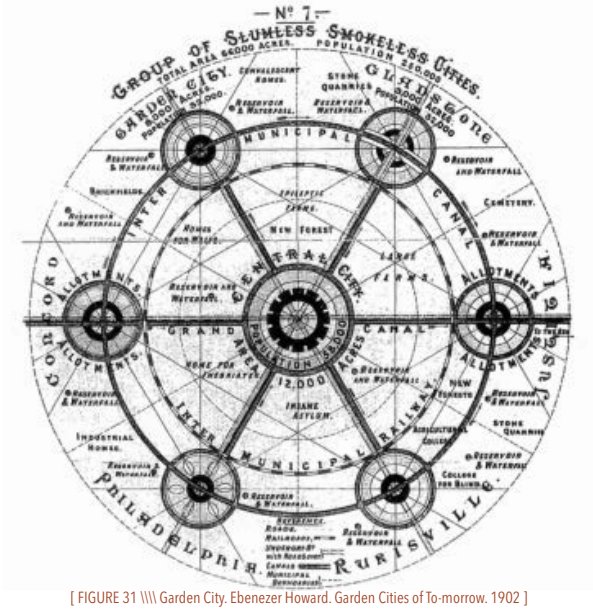
The criteria for an ideal site or settlement on Earth does not work for Mars. Mars is a desert planet with little to no water and no "healthy" sites. An ideal settlement site on mars would have access to water (whatever little there might be), natural landforms for shelter, open areas for landing spacecraft, a location near the equator where seasons shifts are not extreme and sunlight is maximized, not in high elevation areas due to decreased time for atmospheric braking, avoid steep slopes, avoid rocky terrain, and avoid thick layers of dust. Orbiting satellites gather information that is then used to determine the geology of the site, determining if a site is suitable for a settlement.

Future astronauts will need public places to rest, socialize, and congregate, in order to maintain healthy minds and a healthy society—and public as well as private spaces will play a role in working towards a functioning Martian society, and even perhaps, one day, the ideal of a Martian utopia." [105]

The craters provide boundaries for settlements which will restrict what can be done and how extensive the settlement will become. By restricting settlement sizes based on areography (the geography of Mars), settlements will spread to other craters or areas of Mars, thus creating a network of settlements.

Settlements would begin in areas that are determined to have access to precious resources, much like how civilizations on Earth began, close to rivers because of proximity to water and therefore food, as well as transportation.

In terms of arranging large settlements, there are several urban planning methods that could be utilized on Mars. The Garden City by Ebenezer Howard could be a settlement in a crater because of the plans circular form, playing perfectly to the element that industrial manufacturing and infrastructure could sit on the rim of the crater and then greenhouses/hydroponic houses in the inner rings serviced by satellite towns. Then the major city settlement in the centre of the crater, acting as the government of the crater and its inhabitants as well central control centre for each sector. However, the Garden city does isolate communities by vast distances and creates social disconnectivity. At the time the Garden City was conceived, towns were polluted and almost slum like. The industrial revolution had created dirty cities with less than ideal living conditions. Howard wanted to give urban dwellers the best of both city and country living.[106]



[FIGURE 31 \\\\ Garden City. Ebenezer Howard. Garden Cities of To-morrow. 1902]

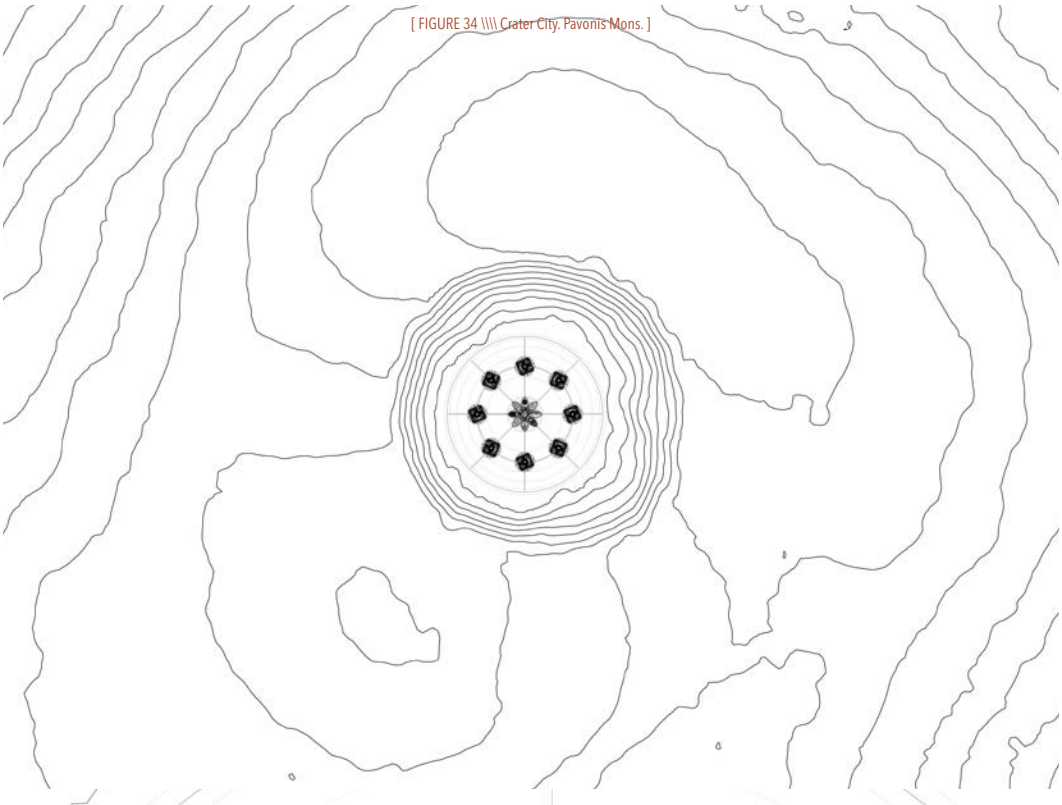

[FIGURE 32 \\\\ Ville Radieuse (The Radiant City). Le Corbusier. Ville Radieuse. 1933]

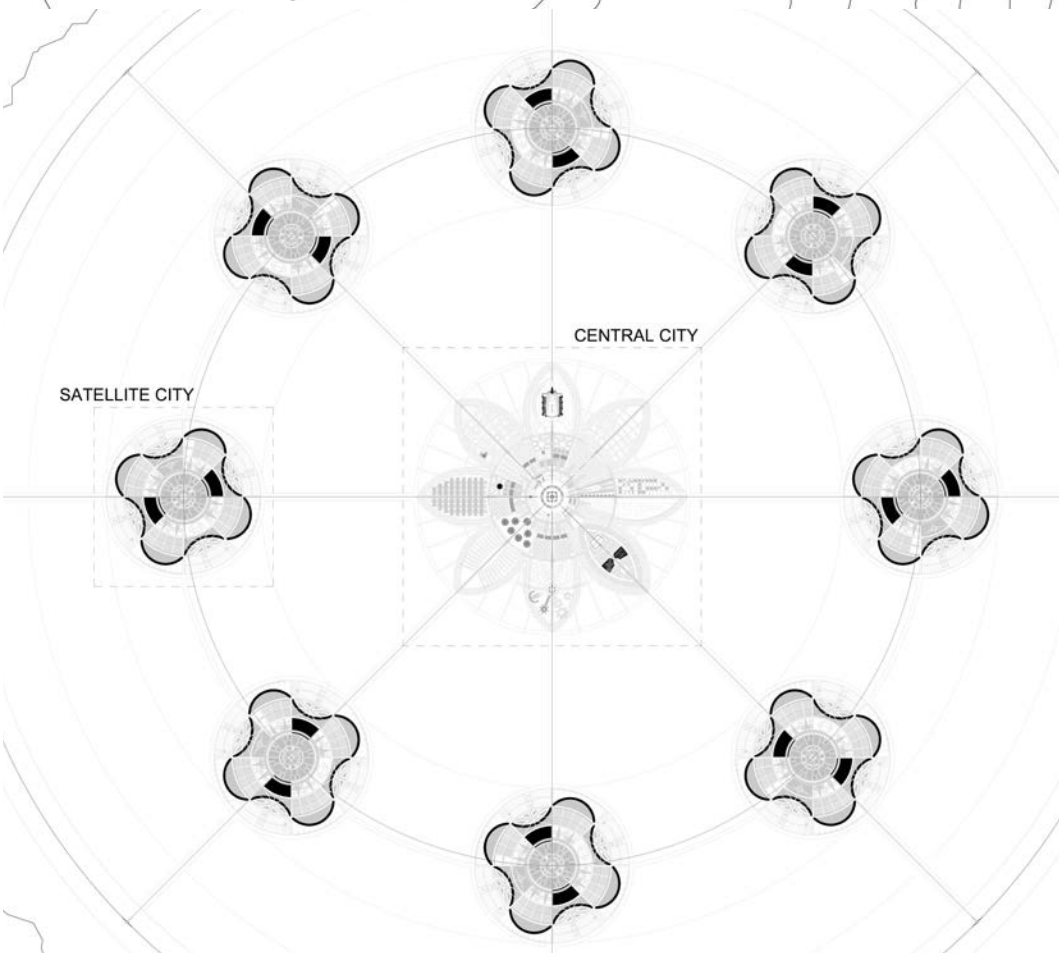

[FIGURE 33 \\\\ Broadacre City. Frank Lloyd Wright. The Frank Lloyd Wright Foundation Archives. 1935]

Le Corbusier's Radiant City looked to find a fix for the same problems of urban pollution and overcrowding as Howard was, but he envisioned building up, not out. His Towers in the Park plan proposed exactly what its name says; high-rise buildings surrounded by green space. Each building was set on superblocks, and space was clearly defined between different uses; residential, commercial, and factories and warehouses. On Mars, Corbusier's Radiant City also sit inside a crater, but could also straddle the side of the cliff face for its verticality and its factories and commercial areas are within the cliff. Mined materials would be used by the industrial sectors.[108 109]

Settlements on Mars will be fluid organisms ever evolving. As more people arrive to the planet, settlements will grow organically to suit the needs of the population. Initial settlements will be small buildings focused around public communal space. As settlements look to more permanent larger forms of architecture, the plan will change to suit. A Martian settlement cannot be one urban plan, it must be many. Incorporating the best ideas of different master plans and fixing the issues that are created by each one. A chimera of urban planning.

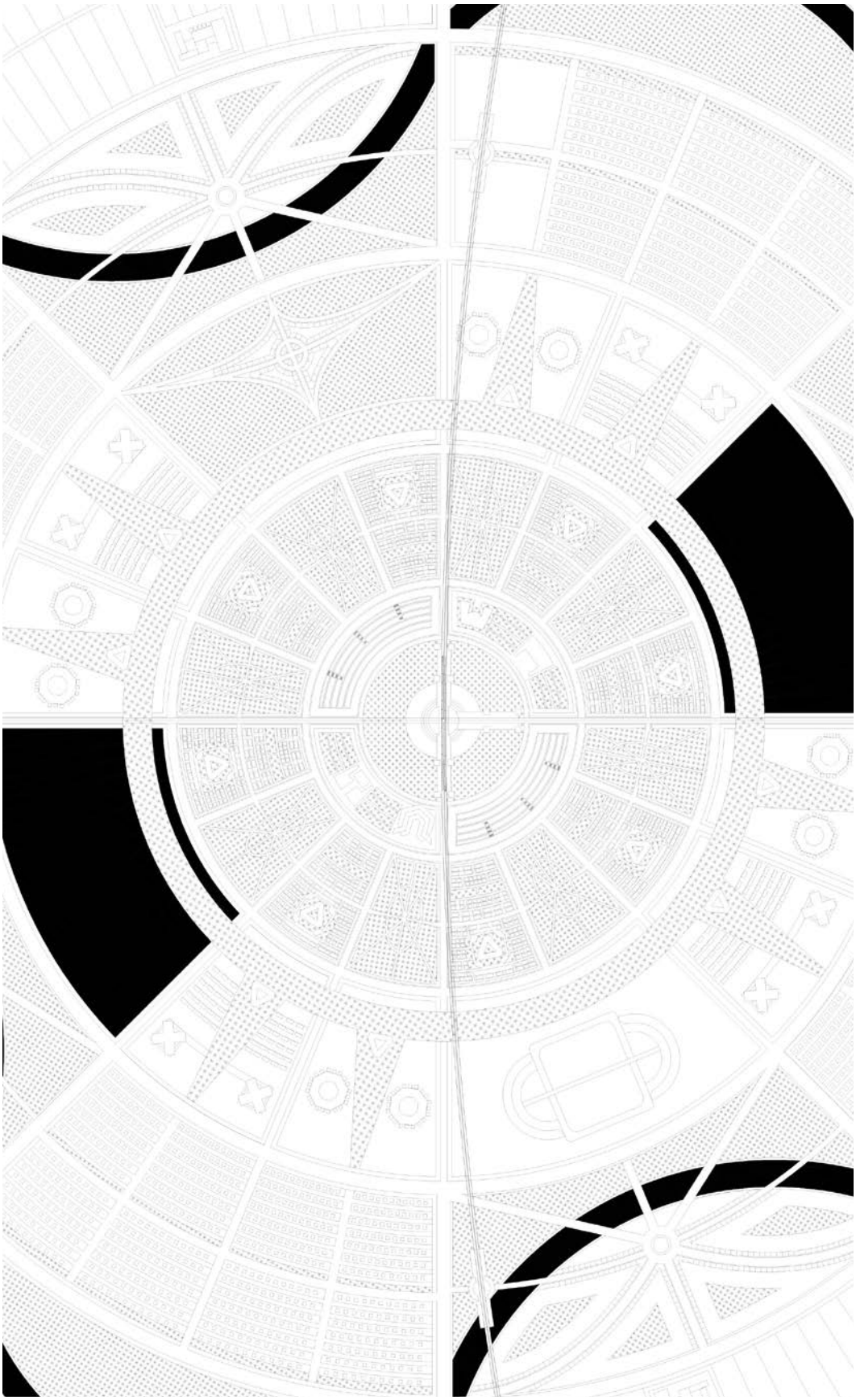
[FIGURE 34 \\\\ Crater City. Pavonis Mons.]



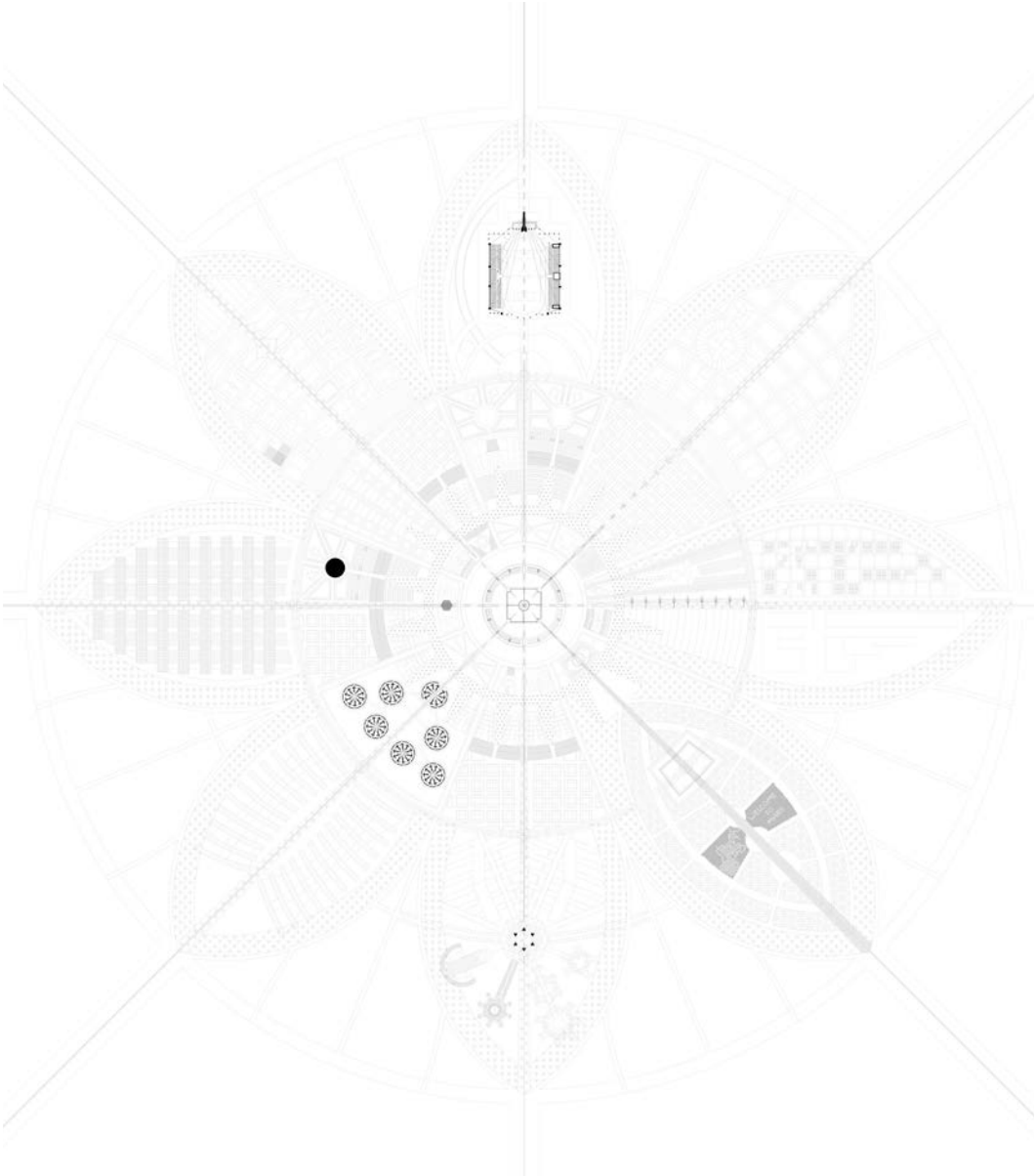


[FIGURE 35 \\\\ Crater City. Pavonis Mons.]

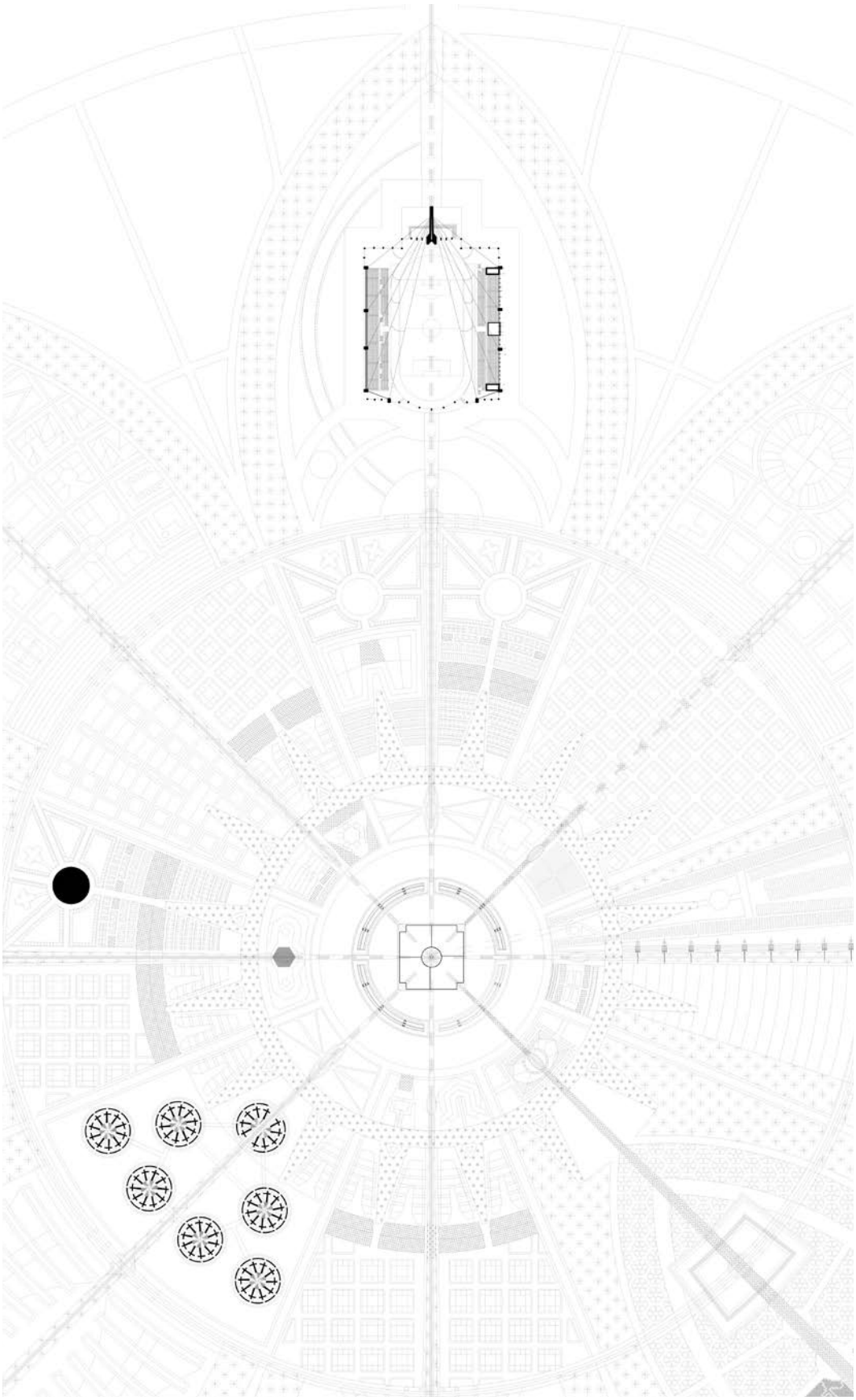
[FIGURE 36 \\\\ Satellite Crater City. Pavonis Mons.]



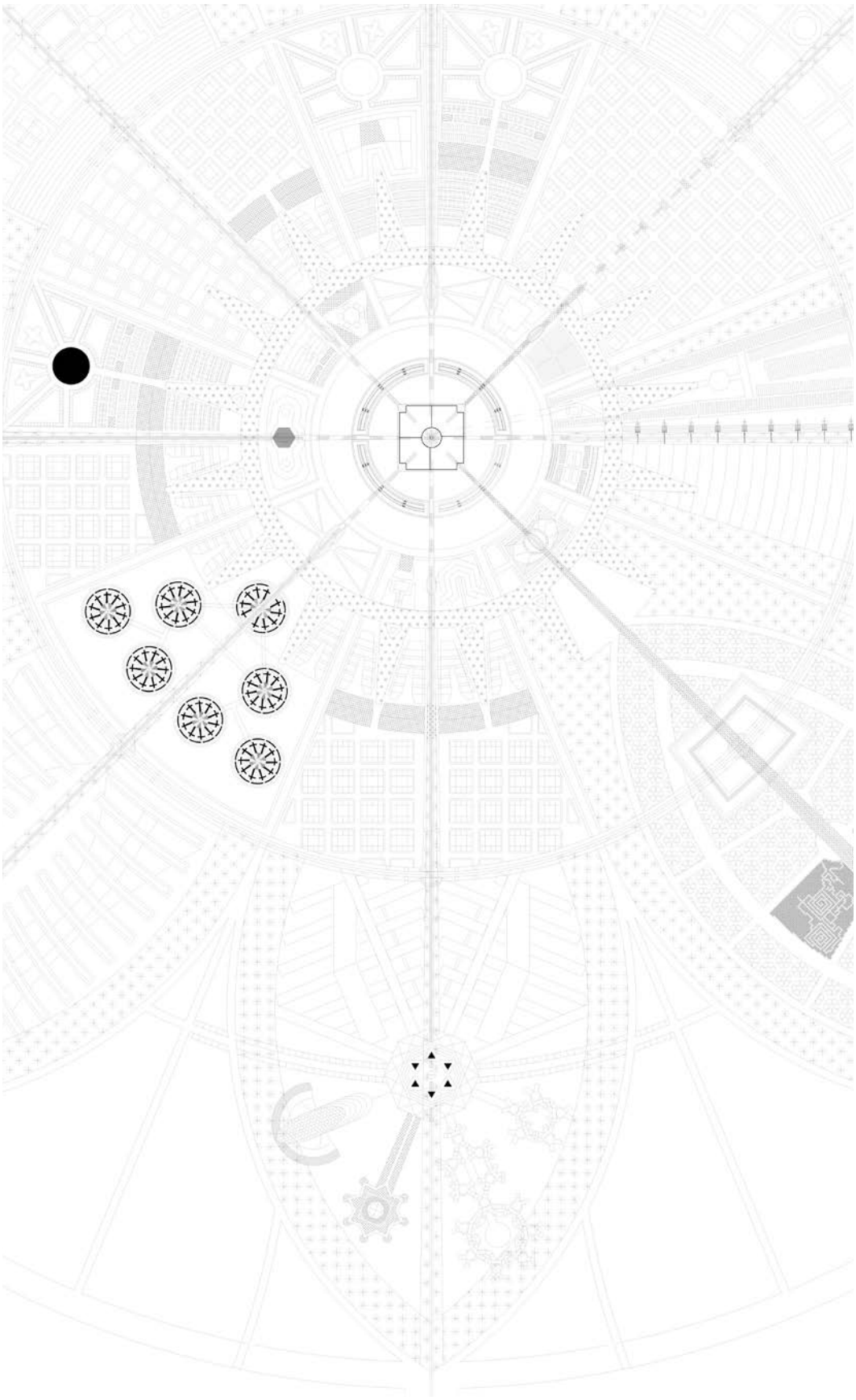
[FIGURE 37 \\\\ Satellite Crater City. Pavonis Mons.]



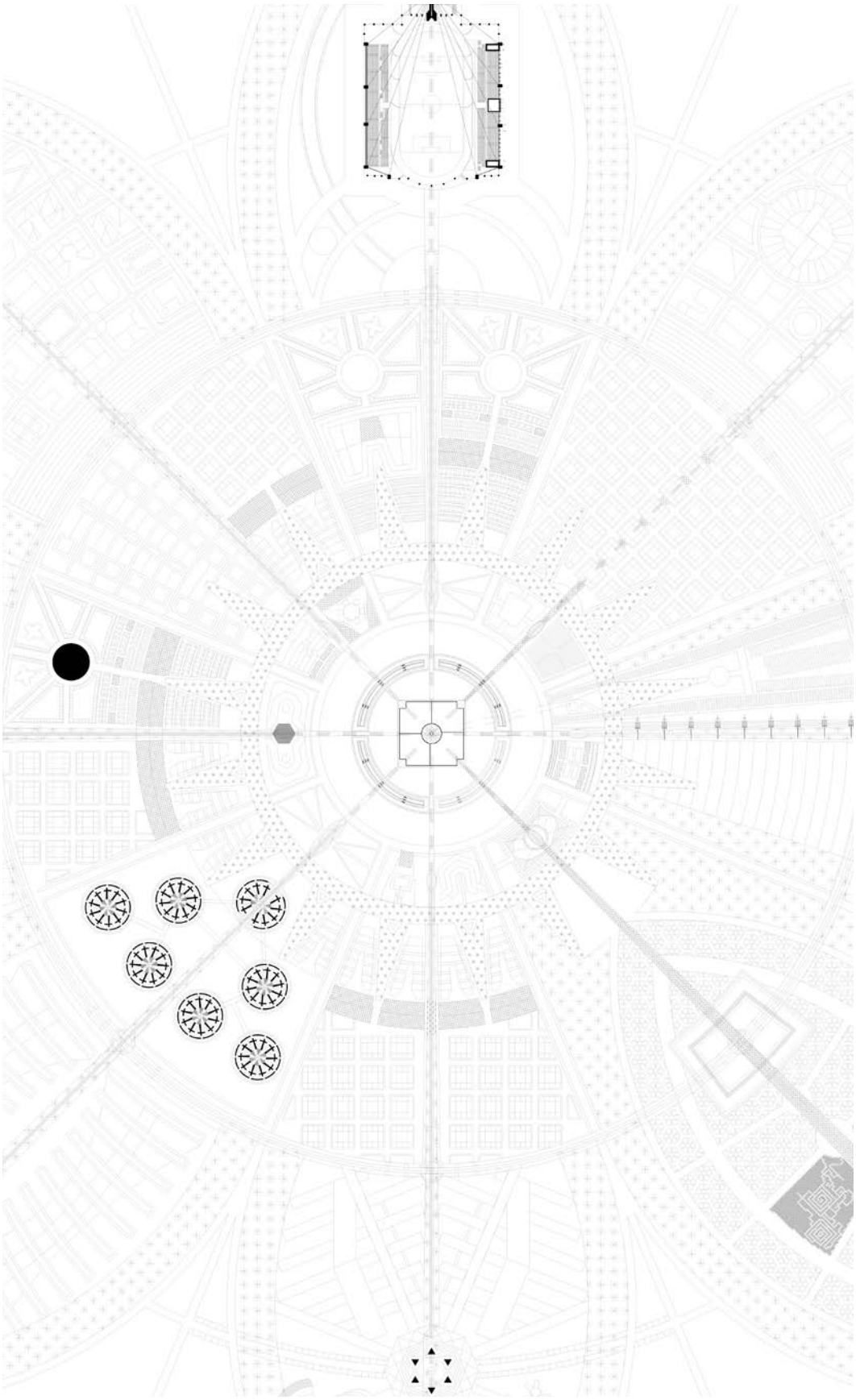
[FIGURE 38 \\\\ Central Crater City. Pavonis Mons.]



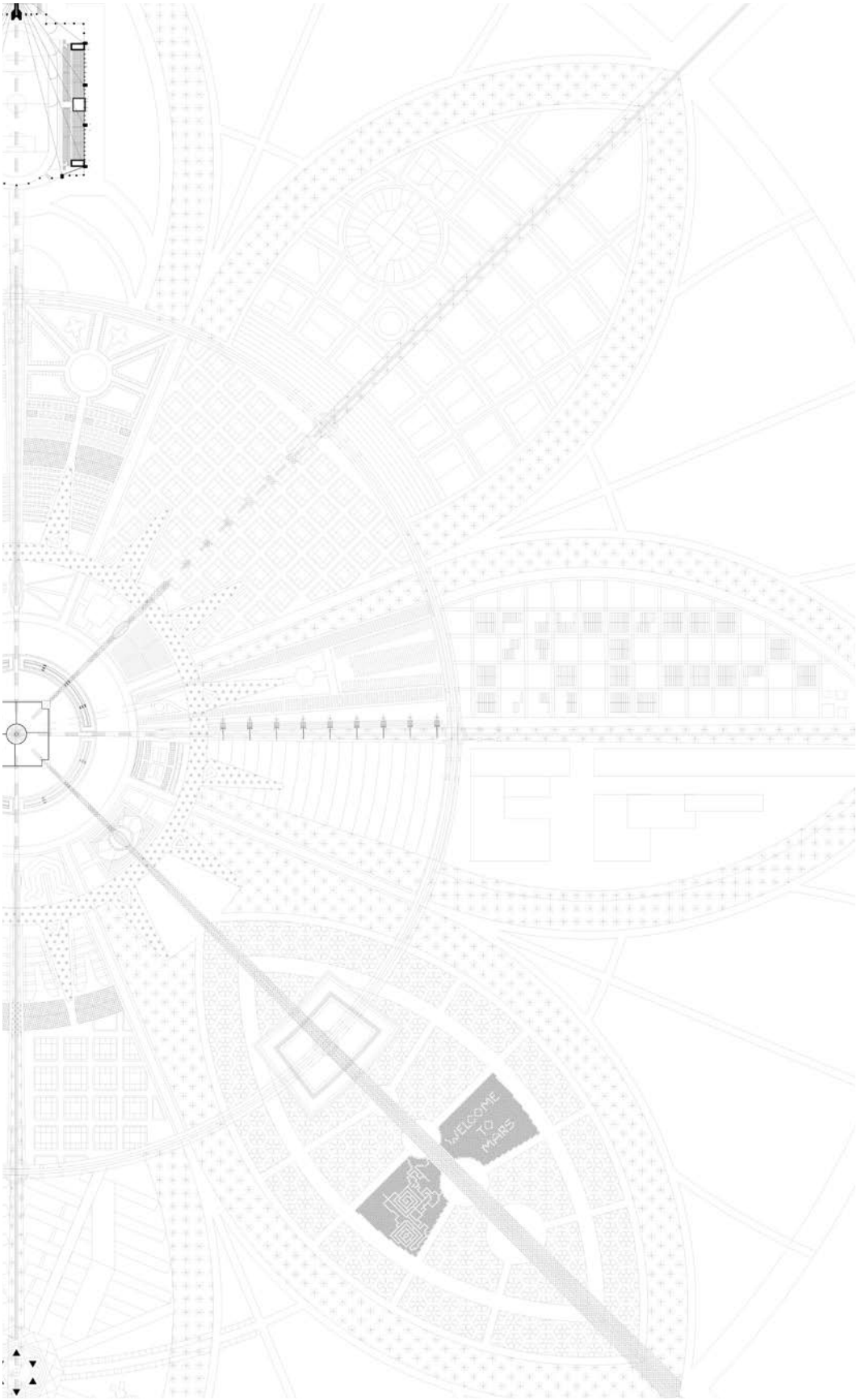
[FIGURE 39 \\\\ Central Crater City. Pavonis Mons.]



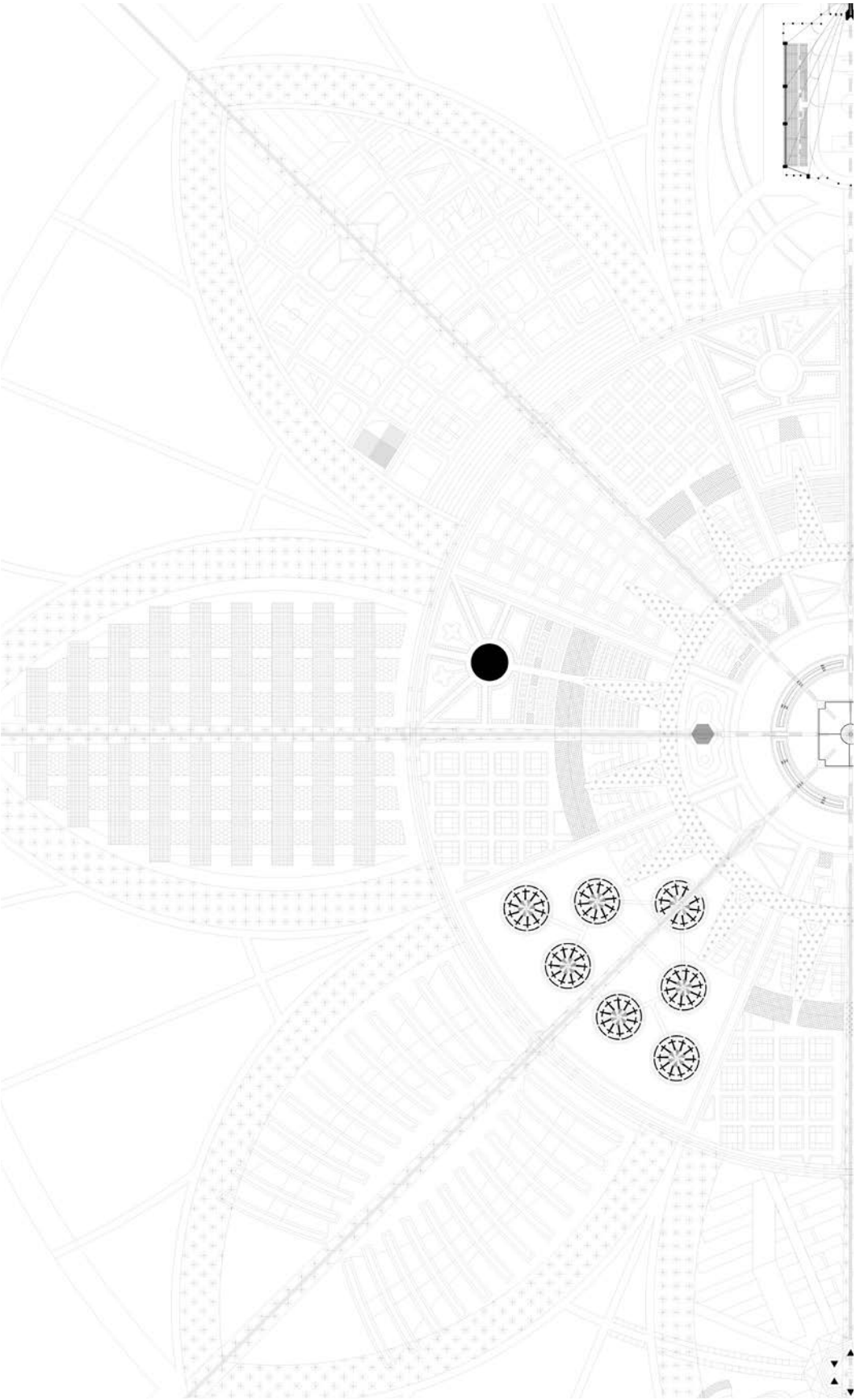
[FIGURE 40 \\\\ Central Crater City. Pavonis Mons.]



[FIGURE 41 \\\\ Central Crater City. Pavonis Mons.]



[FIGURE 42 \\\\ Central Crater City. Pavonis Mons.]



[FIGURE 43 \\\\ Central Crater City. Pavonis Mons.]

MARTIAN ARCHITECTURE

\\\\ SPACE ARCHITECTURE

The first habitats on Mars will be like the four-person space craft that brought the crew to the planet, small and cramped, with all social life centered around a common area like the kitchen. For long-term settlements, the pill/dome-shaped aluminium cans and inflatable structures will need to be covered with a thick layer of rock and dirt to absorb deep space radiation and extreme temperature shifts.

As a Mars settlement expands and becomes more permanent, public gathering spaces will increase in importance. Crews will live in independent habitats, landed across multiple missions and combined into one general area, like a trailer park. Newer buildings would be constructed from glass or concrete made on Mars from in-situ resource utilization machines. Martian masonry and 3D printing would allow for the creation of larger gathering spaces that would bring together the growing Mars population under one roof to maintain a sense of community, and to make decisions that affect the entire group. These gathering spaces will be where the foundations of a Martian civilization are made.

Mars is a deserted planet, every day public spaces will be indoors, massive structures and domed cities of science fiction won't be possible in the near future. The glass-domed cities seen in science fiction would be extremely hot. Daytime surface temperatures reach about 70^0 C, but the glass still wouldn't offer much protection against cosmic radiation. And terraforming is a process that could take thousands of years to make the Martian air breathable for humans.

Crews will need greenhouses to grow food and recreational indoor parks, installing greenery in the public spaces would be impractical in habitats because it would be too difficult to regulate the moisture and oxygen levels. However, incorporating nature into a space can be achieved by locating a greenhouse next to the gathering space, separated by clear glass the greenery and crops that would be visible from the public space, replicating the relaxed stimulation that nature can provide, while maintaining the ideal air quality in each separate space. Other suggestions to introduce nature on Mars would be to design with fractal patterns, curves, interesting textures, the colour green, and piping in the sounds and smells of nature into the public spaces.

The indoor public spaces on Mars will be largely unlike anything built on Earth, but we can look to ancient architectural history for inspiration.

Roman outdoor spaces were enclosed "rooms" for public rituals, proving that interior urbanism can be grand, theatrical and promote civic life. Medieval and Gothic architecture reveals external views sparingly, and still be emotionally and spiritually inspiring. Islamic courtyards bring nature into the center of the home, and modern-day shopping malls provide an airy indoor space for socializing.

These earthly design inspirations offer starting points and the variety of forms allow us to speculate on how public life in outer space would evolve. The interior urbanisms of ancient Rome or a modern-day shopping mall reflect very different types of public gatherings. To what degrees will the space travelling public be determined by government or consumerism, family structure, cooperation with, or independence from Earth? If Mars is a blank slate, is it appropriate for space architects and designers to develop their own interpretations or assumptions about these issues? Or would the settlers/habitants of Mars hold their own attitudes toward these questions, some would agree or disagree. The built environment of Martian settlements, even at the micro scale, would include spaces for navigating both private and public space, and its physical design will affect the limitations of that relation, opening doors to some possibilities while closing others.

Respecting the complexity of this relationship is crucial as a component of both public and private visions of space travel or settlement, particularly as the desire to explore space keeps growing.

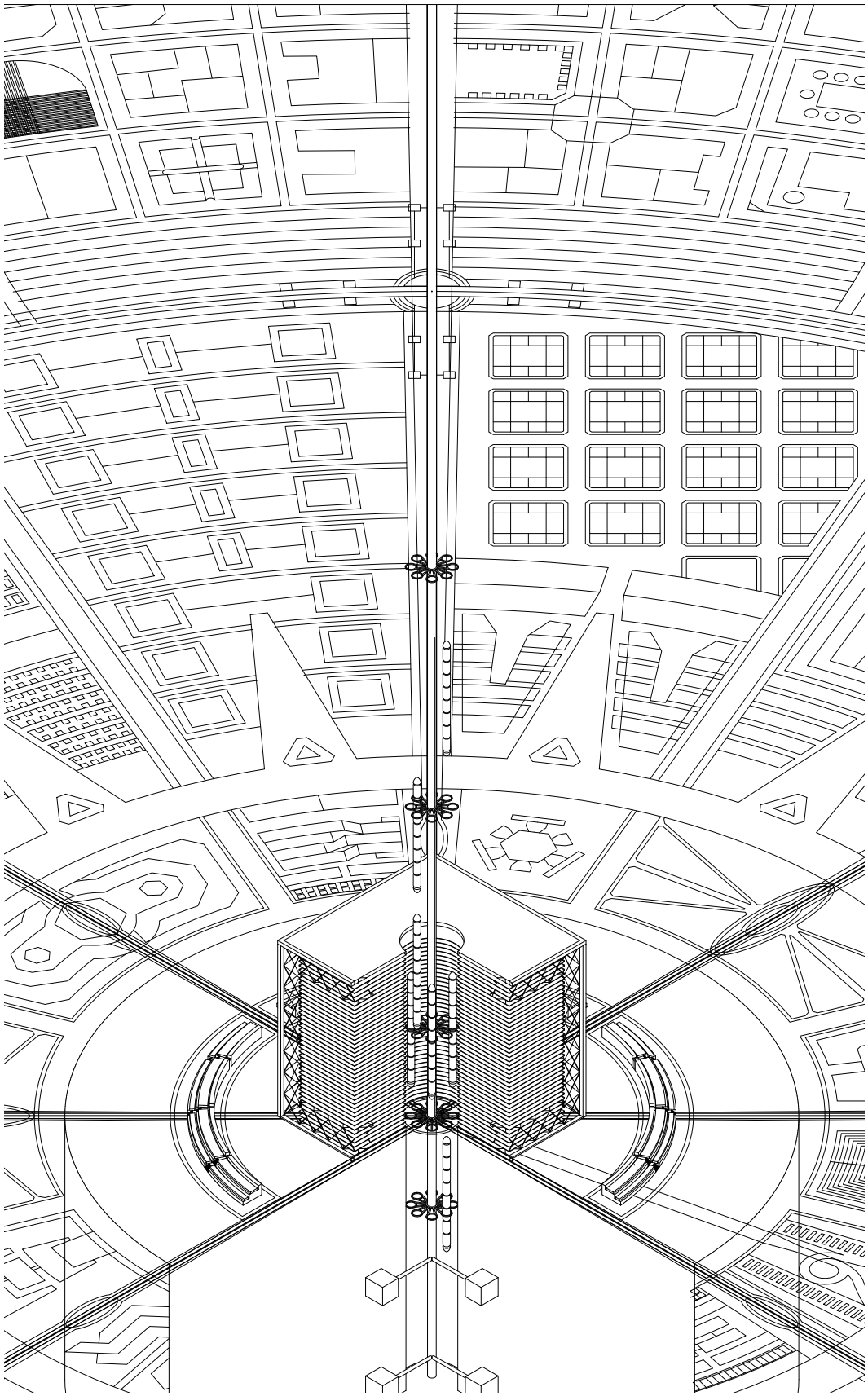
The requirement for a place to meet away from home or work is inevitable. Over time, these public spaces will evolve to house local governments, places for marriages, political discussions, festivals, theatres, funerals, gatherings, etc...

As Martians society grows and becomes self-sufficient, the need to create their own systems government will increase. Martian culture will advance and create its own traditions, jokes, language and culture, which would all evolve from public spaces.

Eventually, as its culture evolves, one could expect that a settlement's interests and values also evolve significantly from those on Earth. History would show that eventually, these settlements could decide to declare their independence from the Earth. You can imagine discussions in private conversations in a small cafe or at large rallies in arenas, as an agora; public spaces could be the gardens where the seeds of the Martian revolution are planted.

Off-Earth innovations, cultural or scientific, won't be restricted to Martians or off-world settlers. The knowledge gained in the stars to solve external issues are ideas that could help humans on any planet; learning how to 3D-print a dwelling using local materials, living off renewable energy in zero-waste environments, and designing cities for inclusivity.

Possibly settling on other worlds would help us save our planet now. The barren surface of Mars represents the extreme end of life on Earth that humans have inadvertently initiated: climate change, ice melting, land degradation, and desertification. Scientific efforts to solve the problem of habitation on Mars may provide clues for helping reverse these processes on Earth or altering their worst effects on human life.



[FIGURE 44 \\\\ Space Elevator Anchor. Central Crater City. Pavonis Mons]

MARTIAN DWELLING

\\ SPACE ARCHITECTURE

The longevity of a settlers mental and physical health is key to the success of settling on Mars or else where in space. Figuring out how we can comfortably live on the red planet is a challenge but with increasing discussion about how to send people to Mars, how do we replace the sensation of the sunshine on your face or grass beneath your feet? How do we make our new home feel like our old one?

When designing homes on Mars, there are some key design aspects to examine; creating privacy and purpose, minimise waste, build with local resources, create greenery, and design familiarity.

Privacy and purpose: architecture firm Hugh Broughton Architects, designers of the Halley VI British Antarctic Research Station, say that the need for privacy and personal space in small living space is critical. To best address this, a house on Mars would need to have small private spaces within a small house and the houses could be grouped in clusters.

In addition to a design that builds in personal space, having a purpose, task or employment will be a key issue when it comes to the psychology of the inhabitants. On Mars, employment could be anything from geology to botany to maintaining life support systems.

Minimise waste: Martian habitats and the space craft that bring them here will need to be designed as closed loop systems, anything and everything should be renewable or recycled: energy, fuel, food and waste. To live on Mars, you must be very efficient in how you live, because it isn't a quick pop to the shop when you run out of anything. Technology that is already proving useful in the developing world can be applied to the extremes of Mars: we will need to grow food, explore and experiment, while recycling air, water and waste with as little energy as possible.

Places that demonstrate living with scarcity, such as the desert, the arctic or even refugee camps might help find ideas for power systems and waste disposal that could be used on another planet. Solar power and composting made from treated human waste are good examples of closed loop techniques.

Local building materials: When humans arrive on Mars, we will need buildings to live and work. Bringing building materials from the Earth will be too costly, we can take certain pre-fab structures with us, but only to a certain point. The first settlers will have to build structures using the planet's own resources. Martian soil is rich in iron oxide, the particles that give Mars its orange red color, silicon dioxide, aluminium oxide, titanium dioxide and sulfur, and more. When sulphur is heated up to 240°C, it becomes liquid, mixed with Martian soil (1mm aggregate size), it solidifies, binding the aggregate and creating concrete.

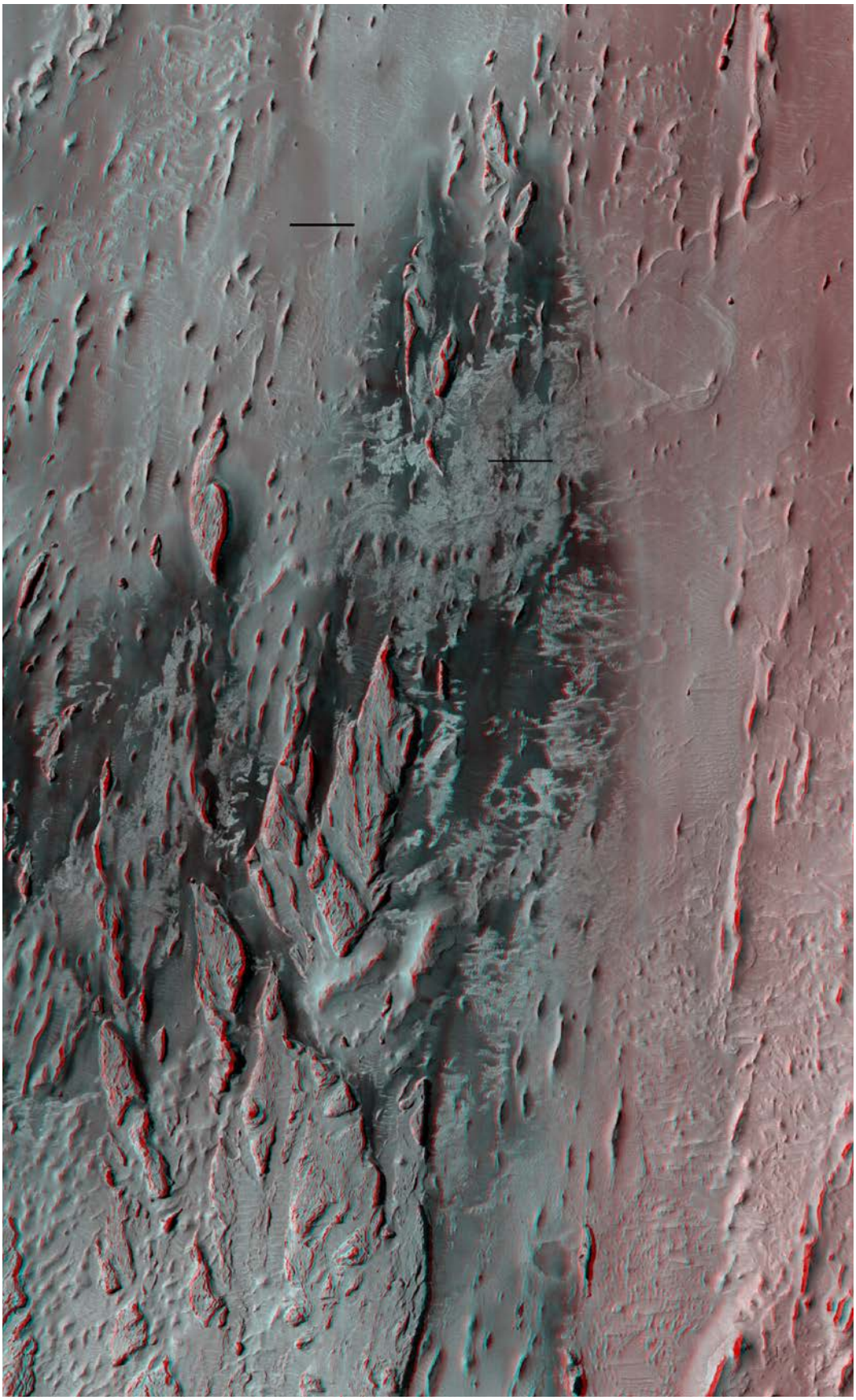
Sulfur concrete made with Martian soil was found to be twice as strong as bricks made on Earth because the sulfur bonds chemically with the minerals found in Martian soil, whereas on Earth the sulfur only serves as glue for the gravel. This means that since gravity on Mars is one-third of that on Earth, the strength is almost tripled. Martian concrete, when compressed during curing can reach a compressive strength of excess to 50 MPa, compared to the standards on Earth of a compressive strength of about 20 MPa. And it solidifies in 1-2 hours. That makes sulfur concrete much more attractive for 3-D printing, which could be the future of construction on Mars. 111

Create Greenery: As of right now, Mars is a desert. When we get to Mars, we will most likely miss the greenery. Hiking through forests of evergreens or walking among the giant red woods. Terraforming Mars is the process of transforming the planet to better suit our needs. The process needing to take centuries or even millennia to complete. So, for now, we will need to build greenhouses not only to grow our crops but also for our mental health. In Japan, forest bathing, or shinrin-yoku, is a common practice. Shinrin in Japanese means "forest," and yoku means "bath." So shinrin-yoku means bathing in the forest atmosphere or taking in the forest through our senses. Its not exercise, or hiking, or jogging. It is just being in nature, connecting with it through our senses of sight, hearing, taste, smell and touch. Shinrin-yoku is like a bridge. By opening our senses, it bridges the gap between us and the natural world. The sounds of the forest, the scent of the trees, the sunlight dancing through the leaves, the fresh, clean air all give us a sense of comfort. They ease our stress and worry, help us to relax and to think more clearly. Being in nature can restore our mood, give us back our energy and vitality, refresh and rejuvenate us.[112] This is key to surviving the harsh extreme landscapes of Mars.

Designing familiarity: Connected to creating greenery, we must design with familiarity in mind. More specifically, familiar sensory experiences. This is again connected to our mental health because as humans, we have attachments, memories and associations to people, things, smells, tastes, visuals, sounds and other objects we interact with. The environments we build impact our ability to function. If we are not mentally healthy on Mars, how would we survive? With the use of augmented reality or actual reality, plants, water features and daily routines – could help create environments that support people's mental health.

By becoming multiplanetary, architecture can continue to evolve. If we can survive in the most extreme landscapes, that building science can translate to make buildings on earth better. Architectural design will also evolve as the needs of humanity change, new advancements technology and building materials will change how we design. Sean Lally's book, **"The Air from Other Planets. A brief history of Architecture to come"**, he discusses that as architecture evolves on new worlds and technology develops, we can design architecture from the energy within the environment; electromagnetic, thermodynamic, acoustic, and chemical.

This type of architecture would transform the walls and hard surfaces that we typically associate with architecture into a range of material energies that develop their own shapes, aesthetics, organizational systems and social experiences. Energy develops into something more than what fills the interior of a building or bounces off its outer walls. The energy forms its own creativity for design innovation, becoming its own architecture.[113] Speculation on the future of architecture shouldn't rely only on existing technology and advancements in building science, but also look to science fiction and the exercise of our imaginations.



[Western Medusa Fossae. HiRISE/ NASA/JPL/University of Arizona]

10

CONCLUSION

Conclusion

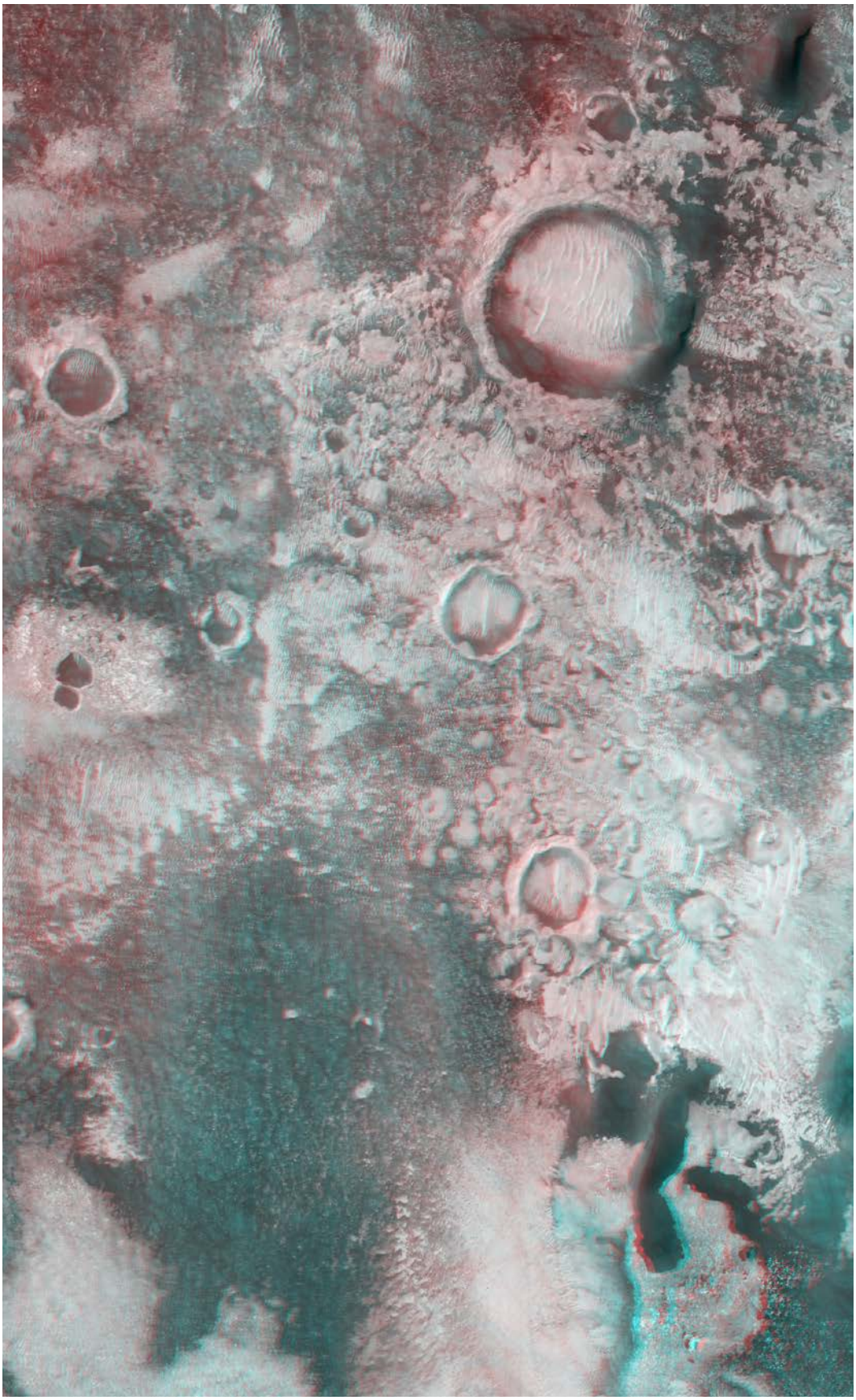
The human body is unsuited for space flight. Until advancements in health technology during space flight allows the safe passage through deep space, we must send machines to Mars to build settlements for us. Then, when we can maintain our health in long term space flight, we can travel across space with our health in tact. We will be able to establish ourselves off the Earth. In **"Journey of a Robotic Architect"** and "**The Medical Logs"**, a brief look is given at why the human body does not favour extended periods of time in space and are shown to explain the need for robots to settle on Mars for Humanity. For the human species to survive, we must reach for deep space or Mars, we can't have all our eggs in one basket in case of some sort of catastrophic event. In the thesis narratives, humanity chooses to travel to Mars because it was the natural next step in our progress as a species. We (humanity) tried to go to mars but failed. Then we sent machines to Mars. The machines work, paving the way for our future on Mars. Artificial intelligence advancements mean that the machines can design and build our cities on Mars for us. Can machines design well? Would a brand-new settlement on Mars, designed by machines with no precedent or previous knowledge, understand the needs of humanity on another planet when We still don't know what to expect when we arrive there or know what we need for a new Martian settlement?

This thesis has been an exercise in architectural storytelling. By writing my own narrative, I can extensively work through fictional truths regarding the settlement of Mars. Martian architecture is speculative, space architecture has its roots established but must evolve into architecture that is both form and function. Martian architecture will follow suit over time when it is better understood what is needed from a settlement on Mars. Marchitects, Mars architects, are working on ways to build structures on Mars using local resources and applying Earthly familiarity to the settlements of Mars. The technology of the building science is not up for debate. We know that cosmic radiation will penetrate through just about anything, and can conclude that to keep safe from that, we must build underground cities to start, or using local materials to 3D print Martian concrete shielding for our own forms of architecture we bring to the planet. We know that temperature shifts are greater than season shifts in Canada and we can implement technology to climatize our environments for us. We know that food and energy production will be limited to what we bring with us or grow on Mars. The Sun can provide solar energy. Nuclear power from space craft could be repurposed to power early settlements. Green houses can grow food for us and provide publics spaces for us to congregate and meet, discuss issues, provide mental health breaks from the stress of Mars.

What we can only speculate on is how a settlement might be organized, what kind of infrastructure might be needed, and our requirements of the public and private spaces? A Martian settlements overall appearance can be influenced from science fiction. We can imagine massive domes spanning entire craters, enclosing cities, allowing people to walk freely amongst themselves without the fear of suffocating. The very first forms of architecture were influenced by nature. Subsequent architectural forms or design all take some sort of influence from the previous era of architecture. Architecture on Mars will not be different, it will take on the forms of previous architectural examples to create new forms to create a new movement, Martian Architecture. A vast database of science fiction gives Martian Architecture a library of influence on what a Mars settlement could be. The possibilities are endless in terms of how architecture might form on the surface of mars.

On the surface, this thesis focuses on humanity settling on Mars, using robots to build our new environments for us. Underneath the narrative, it is about the possibility and meaning of humanity becoming a species that can expand from its home. The thesis examines the restrictions of our natural bodies and our chances of survival, in of both staying on the Earth and in the dangers of outer space.

The narrative is used as a tool to create the scenario of humanity travelling to Mars and making a permanent home on the planet. Through the narrative we can speculate on the future of architecture. Based on architectural history and the issues they addressed, a new form of architecture can evolve into a new era of architectural language. Future architecture is rooted to present day technology, both on the Earth and in space. Space architecture, a precursor to Martian architecture, is primarily a functionalist approach to architecture. On the ISS, each wall panel serves an operation, a set of controls to conduct a task or experiment. These built environments are designed to keep their habitants physically healthy. Space and Martian architecture must transform into an environment that will also keep its users mentally healthy. Transforming the functional spaces into livable and pleasant spaces will ensure the success of future Space and Martian architecture.



[Kaiser Crater. HiRISE/ NASA/JPL/University of Arizona]

11

APPENDIX

MARS FACT SHEET

\\\\ APPENDIX A

Equatorial Diameter:	6,792 km
Polar Diameter:	6,752 km
Mass:	6.42 x 10^23 kg (10.7% Earth)
Moons:	2 (Phobos & Deimos)
Orbital Distance:	227,943,824 km (1.52 AU)
Orbit Period:	687 days (1.9 years)
Day length:	1 SOL (Mars day) = 24 hours, 39 minutes and 35.244 seconds.
Surface Temperature:	-153 to 20 °C
First Record:	2nd millennium BC
Recorded by:	Egyptian astronomers

MARS - EARTH COMPARISON

\\ APPENDIX A

	Mars	Earth	Ratio (Mars/Earth)
Mass (10^{24} kg)	0.64171	5.9724	0.107
Volume (10^{10} km3)	16.318	108.321	0.151
Equatorial radius (km)	3396.2	6378.1	0.532
Polar radius (km)	3376.2	6356.8	0.531
Volumetric mean radius (km)	3389.5	6371.0	0.532
Core radius (km)	1700	3485	0.488
Ellipticity (Flattening)	0.00589	0.00335	1.76
Mean density (kg/m^3)	3933	5514	0.713
Surface gravity (m/s^2)	3.71	9.80	0.379
Surface acceleration (m/s^2)	3.69	9.78	0.377
Escape velocity (km/s)	5.03	11.19	0.450
GM (x 10^6 km^3/s^2)	0.042828	0.39860	0.107
Bond albedo	0.250	0.306	0.817
Geometric albedo	0.170	0.434	0.392
V-band magnitude V(1,0)	-1.60	-3.99	-
Solar irradiance (W/m2)	586.2	1361.0	0.431
Black-body temperature (K)	209.8	254.0	0.826
Topographic range (km)	30	20	1.500
Moment of inertia (I/MR^2)	0.366	0.3308	1.106
J2 (x 10^{-6})	1960.45	1082.63	1.811
Number of natural satellites	2	1	
Planetary ring system	No	No	

MARS - EARTH ORBITAL PARAMETRES COMPARISON

\\ APPENDIX A

	Mars	Earth	Ratio (Mars/Earth)
Semimajor axis (10^6 km)	227.92	149.60	1.524
Sidereal orbit period (days)	686.980	365.256	1.881
Tropical orbit period (days)	686.973	365.242	1.881
Perihelion (10^6 km)	206.62	147.09	1.405
Aphelion (10^6 km)	249.23	152.10	1.639
Synodic period (days)	779.94	-	-
Mean orbital velocity (km/s)	24.07	29.78	0.808
Max. Orbital velocity (km/s)	26.50	30.29	0.875
Min. Orbital velocity (km/s)	21.97	29.29	0.750
Orbit inclination (deg)	1.850	0.000	-
Orbit eccentricity	0.0935	0.0167	5.599
Sidereal rotation period (hrs)	24.6229	23.9345	1.029
Length of day (hrs)	24.6597	24.0000	1.027
Obliquity to orbit (deg)	25.19	23.44	1.075
Inclination of equator (deg)	25.19	23.44	1.075

MARS OBSERVATION PARAMETRES

\\ APPENDIX A

Discoverer:	Unknown
Discovery Date:	Prehistoric
Distance from Earth	
Minimum (10^6 km):	55.7
Maximum (10^6 km):	401.3
Mean values at opposition from Earth	
Distance from Earth (10^6 km):	78.39
Apparent diameter (seconds of arc):	17.9
Apparent visual magnitude:	-2.0

MARS MEAN ORBITAL ELEMENTS

\\ APPENDIX A

Semimajor axis (AU)	1.52366231
Orbital eccentricity	0.09341233
Orbital inclination (deg)	1.85061
Longitude of ascending node (deg)	49.57854
Longitude of perihelion (deg)	336.04084
Mean Longitude (deg)	355.45332

MARS NORTH POLE OF ROTATION

Right Ascension:	317.681 - 0.106T
Declination:	52.887 - 0.061T
Reference Date:	12:00 UT 1 Jan 2000
	(JD 2451545.0)

T = Julian centuries from reference date

MARTIAN ATMOSPHERE

\\ APPENDIX A

Surface Pressure:	6.36 mb at mean radius (variable from 4.0 to 8.7 mb depending on season) [6.9 mb to 9 mb (Viking 1 Lander site)]
Surface Density:	~0.020 kg/m^3
Scale Height:	11.1 KM
Total Mass of Atmosphere:	~2.5 x 10^{16} kg
Average Temperature:	~210 K (-63 C)
Diurnal Temperature Range:	184 K to 242 K (-89 to -31 C) (Viking 1 Lander site)
Wind Speeds:	2-7 m/s (summer), 5-10 m/s (fall), 17-30 m/s (dust storm)
Mean Molecular Weight:	43.34
Atmosphere Composition: (By volume)	
Major:	Carbon Dioxide (CO_2) - 95.32% ; Nitrogen (N_2) - 2.7% Argon (Ar) - 1.6%; Oxygen (O_2) - 0.13%; Carbon Monoxide (CO) - 0.08%
Minor (ppm):	Water (H_2O) - 210 Nitrogen Oxide(NO) - 100 Neon(Ne) - 2.5 Hydrogen - Deuterium - Oxygen (HDO) - 0.85 Krypton(Kr) - 0.3 Xenon(Xe) - 0.08

MARS SATELLITES

\\ APPENDIX A

	Phobos	Deimos
Semimajor axis* (km)	9378	23459
Sidereal orbit period (days)	0.31891	1.26244
Sidereal rotation period (days)	0.31891	1.26244
Orbital inclination (deg)	1.08	1.79
Orbital eccentricity	0.0151	0.0005
Sub-planetary axis radius (km)	13.0	7.8
Along-orbit axis radius (km)	11.4	6.0
Polar axis radius (km)	9.1	5.1
Mass (10^{15} kg)	10.6	2.4
Mean density (kg/m^3)	1900	1750
Geometric albedo	0.07	0.08
Visual magnitude V (1,0)	+11.8	+12.89
Apparent visual magnitude (V_0)	11.3	12.40

ZERO GRAVITY TOILET

\\\\ APPENDIX B

Note\\ As seen in Stanley Kubrick's **2001: A Space Odyssey.** The instructions are seen only momentarily during Dr. Heywood Floyd's flight to the Clavius base on the Moon. They are not only extremely detailed, but they actually describe a plausible lavatory suited for "Zero G" flight.

1. The toilet is of the standard zero-gravity type. Depending on requirements, System A and/or System B can be used, details of which are clearly marked in the toilet compartment. When operating System A, depress lever and a plastic dalkron eliminator will be dispensed through the slot immediately underneath. When you have fastened the adhesive lip, attach connection marked by the large "X" outlet hose. Twist the silver coloured ring one inch below the connection point until you feel it lock.

2. The toilet is now ready for use. The Sonovac cleanser is activated by the small switch on the lip. When securing, twist the ring back to its initial-condition, so that the two-orange line meet. Disconnect. Place the dalkron eliminator in the vacuum receptacle to the rear. Activate by pressing the blue button.

3. The controls for System B are located on the opposite wall. The red release switch places the uroliminator into position; it can be adjusted manually up or down by pressing the blue manual release button. The opening is self adjusting. To secure after use, press the green button which simultaneously activates the evaporator and returns the uroliminator to its storage position.

4. You may leave the lavatory if the green exit light is on over the door. If the red light is illuminated, one of the lavatory facilities is not properly secured. Press the "Stewardess" call button on the right of the door. She will secure all facilities from her control panel outside. When green exit light goes on you may open the door and leave. Please close the door behind you.

5. To use the Sonoshower, first undress and place all your clothes in the clothes rack. Put on the velcro slippers located in the cabinet immediately below. Enter the shower. On the control panel to your upper right upon entering you will see a "Shower seal" button. Press to activate. A green light will then be illuminated immediately below. On the intensity knob select the desired setting. Now depress the Sonovac activation lever. Bathe normally.

6. The Sonovac will automatically go off after three minutes unless you activate the "Manual off" over-ride switch by flipping it up. When you are ready to leave, press the blue "Shower seal" release button. The door will open, and you may leave. Please remove the velcro slippers and place them in their container.

7. If the red light above this panel is on, the toilet is in use. When the green light is illuminated you may enter. However, you must carefully follow all instructions when using the facilities during coasting (Zero G) flight. Inside there are three facilities: (1) the Sonowasher, (2) the Sonoshower, (3) the toilet. All three are designed to be used under weightless conditions. Please observe the sequence of operations for each individual facility.

8. Two modes for Sonowashing your face and hands are available, the "moist-towel" mode and the "Sonovac" ultrasonic cleaner mode. You may select either mode by moving the appropriate lever to the "Activate" position.

9. If you choose the "moist-towel" mode, depress the indicated yellow button and withdraw item. When you have finished, discard the towel in the vacuum dispenser, holding the indicated lever in the "active" position until the green light goes on...showing that the rollers have passed the towel completely into the dispenser. If you desire an additional towel, press the yellow button and repeat the cycle.

10. If you prefer the “Sonovac” ultrasonic cleaning mode, press the indicated blue button. When the twin panels open, pull forward by rings A & B. For cleaning the hands, use in this position. Set the timer to positions 10, 20, 30 or 40...indicative of the number of seconds required. The knob to the left, just below the blue light, has three settings, low, medium or high. For normal use, the medium setting is suggested.

11. After these settings have been made, you can activate the device by switching to the “ON” position the clearly marked red switch. If during the washing operation, you wish to change the settings, place the “manual off” over-ride switch in the “OFF” position. You may now make the change and repeat the cycle.

SCI-FI LITERATURE AND MOVIES

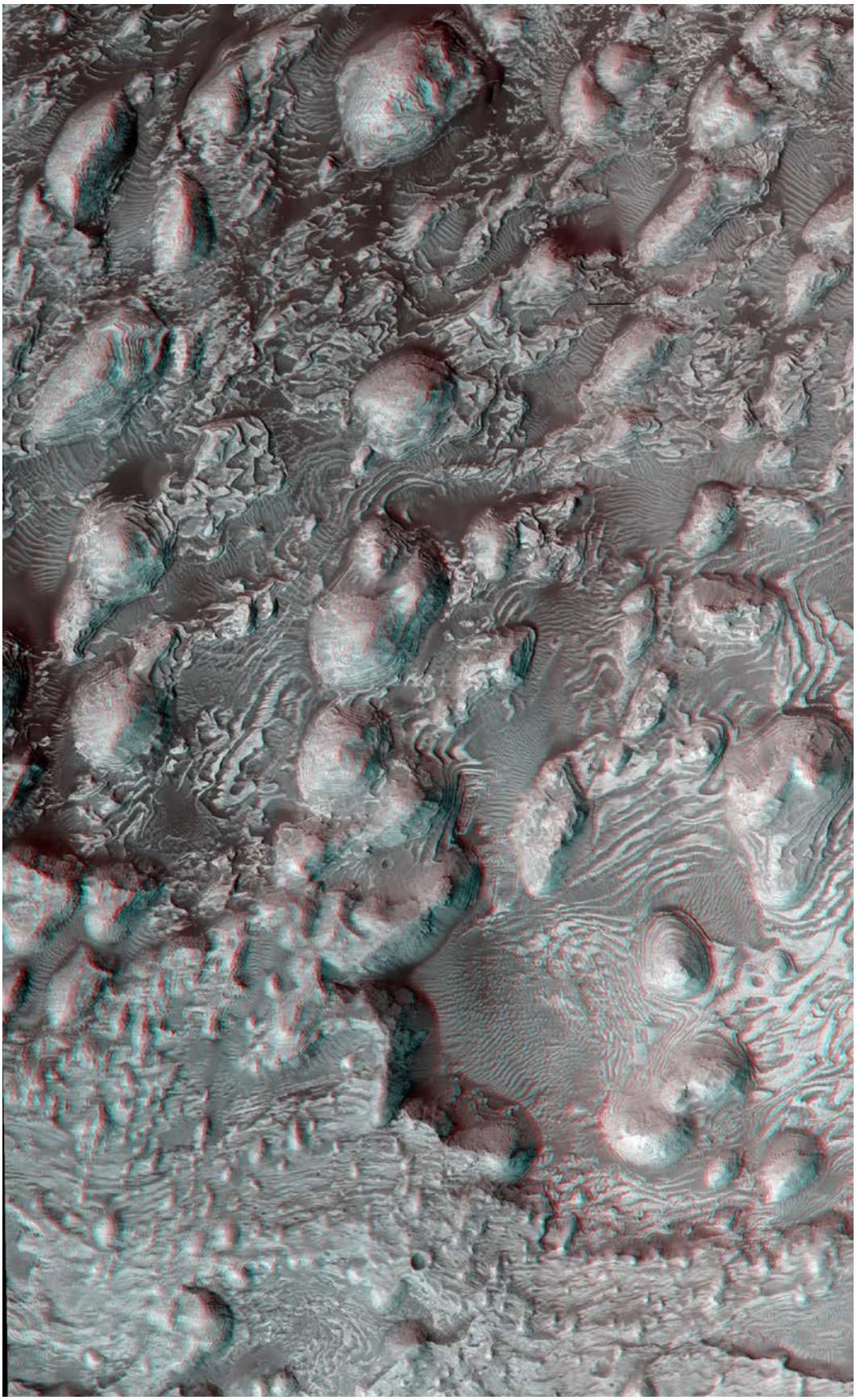
\\\\ APPENDIX C

Literature.

- Hitch Hikers Guide to the Galaxy – Douglas Adams, 1979.
- From the Earth to the Moon – Jules Verne, 1865
- Neuromancer – William Gibson, 1984
- 1984 – George Orwell, 1949
- Do Androids Dream of Electric Sheep? – Philip K. Dick, 1968
- I, Robot – Isaac Asimov, 1950
- Mars Triliogy – Kim Stanley Robinson, 1992 - 1996
- Foundation Series – Isaac Asimov, 1942 – 1993
- Martian Chronicles – Ray Bradbury, 1950
- The Sentinel – Arthur C. Clarke, 1948
- Star Maker – Olaf Stapledon, 1937
- Frankenstein – Mary Shelley, 1823
- Ready Player One – Ernest Cline, 2011
- Stardust – Neil Gaiman, 1999
- Contact – Carl Sagan, 1985
- The Complete Cosmicomics – Italo Calvino, 1965
- Citizens of No Place – Jimenez Lai, 2012
- The Flying City and Beyond – Georgii Krutikov, 2015
- The Martian – Andy Weir, 2011

Movies

- Star Wars, entire saga – George Lucas, 1977 – 2019
- Star Trek: Original Series/Motion Picture – Gene Roddenberry, 1966
- Blade Runner – Ridley Scott, 1982
  (Do Androids Dream of Electric Sheep?)
- The Matrix trilogy – Wachowskis, 1999 - 2003
- 2001: A Space Odyssey, 1968
- Wall-E – Andrew Stanton, 2008
- Back to the Future – Robert Zemeckis, 1985
- Aliens – James Cameron, 1986
- Metropolis – Fritz Lang, 1927
- A.I. Artificial Intelligence – Steven Spielberg, 2001
- Planet of the Apes – Robert Zemeckis, 1989
- The Man Who Fell to Earth – Nicolas Roeg, 1976
- The Day the Earth Stood Still – Robert Wise, 1951
- The Fifth Element – Luc Besson, 1997
- Starship Troopers – Paul Verhoeven, 1997
- E.T. the Extra-Terrestrial – Steven Spielberg, 1982
- Titan A.E. – Don Bluth, Gary Goldman, 2000
- The Fountain – Darren Aronofsky, 2006
- The Martian – Ridley Scott, 2015
- Ex Machina – Alex Garland, 2015



[Firsoff Crater. HiRISE/ NASA/JPL/University of Arizona]

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ENDNOTES

ENDNOTES

INTRODUCTION

A LETTER FROM CARL SAGAN

1. May 25, 2008, the Phoenix safely landed upon Mars. It carried with it a DVD made of silica glass, designed to last the tens, hundreds or thousands of years it may take for humans to visit Mars and to rediscover it. It contained messages and artworks chosen for future visitors to discover when humans eventually travel to the planet. Among them was a message from the late Carl Sagan.

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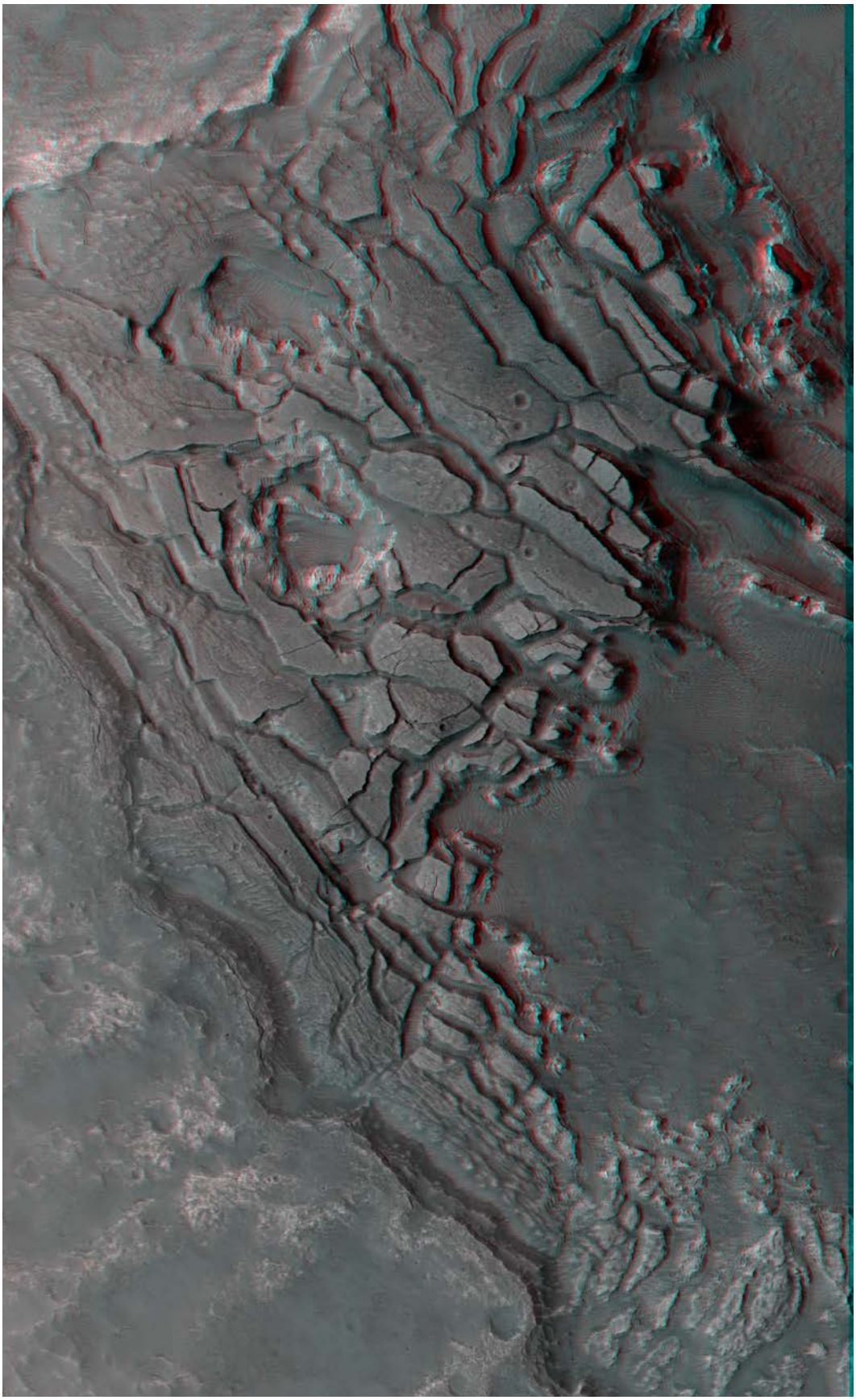

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All Satellite images from the **High Resolution Imaging Science Experiment** (HiRISE) are Anaglyphs; Created from stereo pairs, these images show Martian terrain in 3D relief. Taken from NASA's Jet Propulsion Laboratory, a division of the California Institute of Technology in Pasadena, Calif., manages the Mars Reconnaissance Orbiter for NASA's Science Mission Directorate, Washington. The HiRISE camera was built by Ball Aerospace and Technology Corporation and is operated by the University of Arizona.

[Mars. The Red Planet/ NASA/JPL]