Mars: A Second Home - Full Space Program Proposal & Mars Colonization Research Report

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Loyola Marymount University

FYS: Becoming A Multi-Planetary Species

Prof. Claire Leon and Prof. Michael Noltemeyer

April 2021

MARS: A SECOND HOME

Full Space Program Proposal & Mars Colonization Research Report

by Tomasz (Tomi) Maksymilian Kufel,

Federico Zampedri, Kara Reiss and Mason Friesch

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Program Timeline Overview

1. **Phase 1** - Preliminary Missions
   1.1. Lunar Testing and Outpost Set Up **(2024 - 2032)**
   1.2. Launch Robot Supply Mission to Mars
      1.2.1. **Est. Launch Date: July 2033**
      1.2.2. **Est. Arrival Date: April 2034**
   1.3. Robots Begin Preparation Efforts Prior to Arrival of Crew **(2034 - 2036)**

2. **Phase 2** - Manned Missions to Mars
   2.1. Astronaut Training/Selection **(2022 - 2035)**
   2.2. Launch First Manned Mission to Mars' Surface
      2.2.1. **Est. Launch Date: September 2035**
      2.2.2. **Est. Arrival Date: June 2036**
   2.3. First Martian Crew Set Ups Habitats On Mars' Surface **(2036 - 2037)**
   2.4. Launch Second Manned Mission to Mars' Surface
      2.4.1. **Est. Launch Date: November 2037**
      2.4.2. **Est. Arrival Date: August 2038**
   2.5. Second Crew Completes Habitats on Mars' Surface **(2038 - 2040)**

Note: All rocket launch years and months are synchronized with the approximately calculated Hohmann Transfer Orbit windows for Mars in order to ensure the most optimal launch date minimizing travel time and energy.[1]

3. **Phase 3** – Settlement Missions and Colony Expansion Initiative **(2040 - 2200)**
   3.1. Development of a Self-Sustaining Colony
   3.2. Creation of a steady Interplanetary Transport System

[1] Kim Orr, NASA, and Jet Propulsion Laboratory, "Educator Guide: Calculating Launch Windows," accessed April 10, 2021, https://www.jpl.nasa.gov/edu/teach/activity/lets-go-to-mars-calculating-launch-windows/; John D. Anderson, "Hohmann Transfer Orbit," in *Encyclopedia of Planetary Science*, Encyclopedia of Earth Science (Dordrecht: Kluwer Academic Publishers, 1997), 309–10, https://doi.org/10.1007/1-4020-4520-4_174; Hanneke Weitering, "Can a Starship Reach Mars by 2024?," Space.com, October 17, 2020, https://www.space.com/spacex-starship-first-mars-trip-2024; Jamie Carter, "Why Three Spacecraft Must Leave For The Red Planet Within Weeks Or Miss Their Chance," July 8, 2020, https://www.forbes.com/sites/jamiecartereurope/2020/07/08/mars-alert-why-three-spacecraft-must-leave-for-the-red-planet-within-days-or-miss-their-chance/?sh=5405237f5f93.

Introduction and Mission Goals

by Tomi Kufel

As our technological capabilities increase with a matching enthusiasm for space travel, Mars is steadily becoming a more viable prospect for human settling. Our student team, composed of both engineering and film production majors, strongly believes that colonizing Mars will help us advance our society into the next stage of human civilization: a prospering space-faring multi-planetary species.

Colonizing Mars is an inevitable step in the evolution of mankind. By the end of the 21st century, we will see humans living on Mars, and we are here with the vision to make it happen. Concept art illustration by Michal Kváč (KVACM).[2]

Our spaceflight program "MARS: A SECOND HOME", is focused on laying down the very foundation for a self-sustaining colony on Mars by the year 2040. We believe that by colonizing Mars, we will safeguard mankind's survival in the centuries to come, ignite human ingenuity to go beyond the limits of present day technologies, strengthen international relations, access untapped resources of our solar system to boost global economy, uncover the secrets of our

[2] Michal Kváč, "Martian Colony," June 14, 2017, https://www.deviantart.com/kvacm/art/Martian-Colony-686418848.

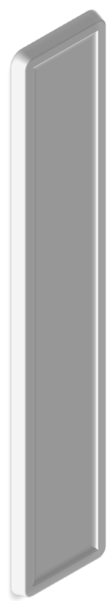
universe, and offer a worldwide pursuit that will inspire our species to live lives filled with meaning and anticipation for the 21st century. We want the future to be exciting and abundant with new opportunities. Our program will launch a new period of exponential progress in the space industry. Each phase of our program will chart a series of historic milestones, raising the cap of human potential, with each milestone awakening the world with awe and inspiration. Our spaceflight program embarks on a quest that tackles some of the greatest technological challenges, all in the effort to launch us into a new multi-planetary age in the history of mankind. To successfully accomplish this goal, our space program encapsulates all the various aspects that are critical to the process of setting up a successful colony. In-situ resourcefulness, long-term sufficiency, and astronaut safety are at the forefront of our design. The research makes use of a variety of sources, from academic journals and online publications, to concept art and science-fiction films. A blend of the presently practical and theoretical. The end product of our multi-faceted research details a comprehensive program architecture that is structured into three distinct phases.

The first phase focuses on using the Moon as a testing ground for all our mission-critical technologies and crew training, extraction of valuable Lunar resources, and the set up of a refueling outpost from which remotely commanded artificial intelligence will be sent to Mars in preparation for the arrival of the first human crew.

The second phase will see rocket launches of the best and brightest of mankind to Mars, with the objective to advance the construction of in-situ resource utilization technologies as well as the necessary infrastructure for the creation of our first Martian city.

The third phase goes beyond to address the future visions we have for Mars from the year 2040 and onwards, overviewing concept technologies which will truly make Mars, our second home.

Phase 1

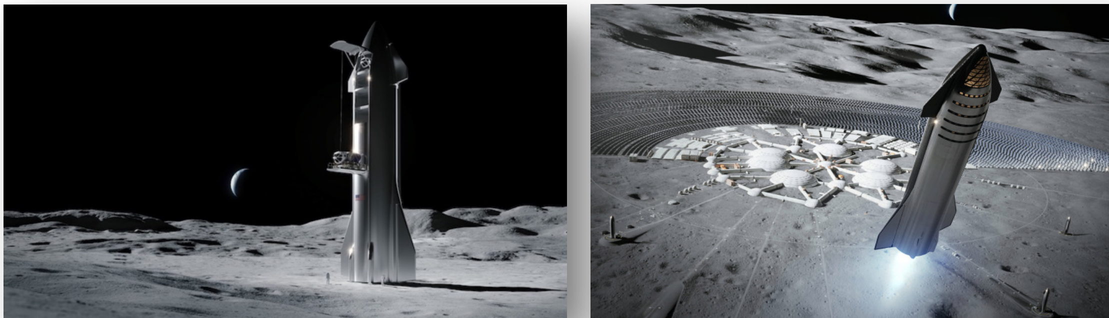


'The Moon is the first milestone on the road to the stars.'
— Arthur C. Clarke, science fiction writer.[3]

[3] The Phi Delta Kappan, "The Bitter Problem of Priorities," *The Phi Delta Kappan* 51, no. 1 (1969): 1.

| Phase 1 Introduction |

by Tomi Kufel



Concept illustration of a Lunar outpost development;
from first landing to infrastructure construction.[4]

In order to ensure success of our mission on Mars, we have to first test our technologies and prepare them for the challenges of the space environment. The Moon provides an ideal setting for ensuring our readiness for this. It is significantly closer to us than the red sphere with a travel time of a few days instead of months, and replicates many of the obstacles we will face on Mars. We will be able to test: protection from extreme temperatures and radiation, low-gravity fitness regimens, in-situ resource extraction, automated A.I. habitat construction, and functioning of our human self-sufficiency supply systems (from crop production to waste management).

Throughout **Phase 1**, various reusable rocket flights to the Moon and back will take place to test our technologies and procedures in close cooperation with our main partner, SpaceX. This phase will also embrace the cooperation with various other pioneers in the space industry, which will specialize in different mission-critical technologies and departments our program is comprised of. With our presence and testing on the Moon, we hope to establish a major cutting-edge

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[4] SpaceX, "Starship Lunar Landing at Moon Base Alpha," April 30, 2020, https://www.instagram.com/p/B_nPifJlmYK/; SpaceX, "Starship Lunar Takeoff," September 29, 2019, https://www.instagram.com/p/B2-meu8FPfE/.

international outpost with resource extraction abilities that will begin construction in 2024, scheduled for completion by 2032. This outpost will serve as both a refueling station and a launch-pad to send our first supplies to Mars in 2033. The arrival of this supply mission will mark the final stage for Phase 1, which will be the cornerstone for completion of all preparations prior to the arrival of the first humans on Mars.

| The Lunar Outpost |

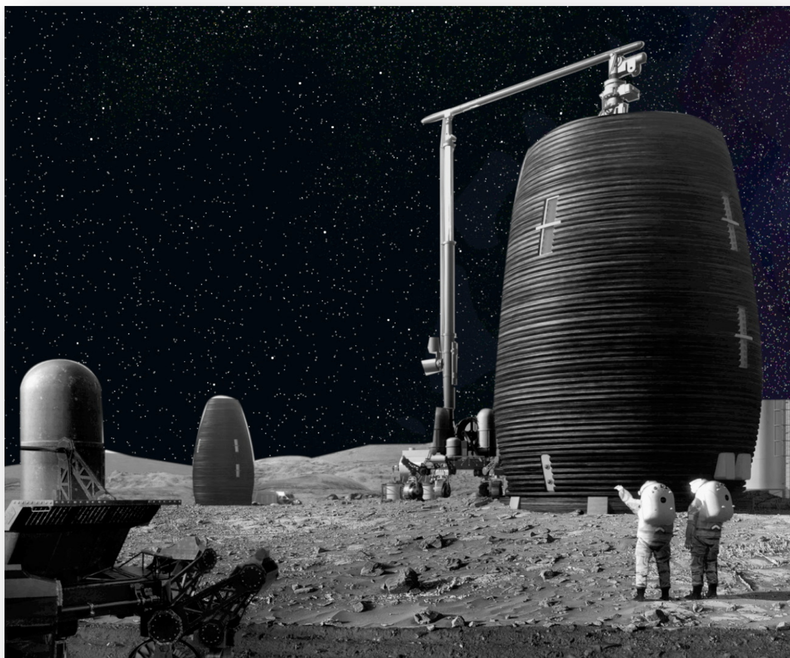
Technology Testing and Crew Preparation on The Moon

by Tomi Kufel

Whilst the Lunar operations are an additional investment into our program, this venture is part of our success strategy that will help save resources and cut down on mission costs in the long-run. Conducting major tests of our technologies and procedures on the nearby Moon is both a safer and a significantly more economical alternative than testing on Mars. In the case of unexpected events or technical failure, we will be able to respond more quickly to any emergencies. Ground control can contact the Lunar crew almost instantaneously with a minimal lag, compared to a 5-30 minute contact delay between Earth and Mars.[5] In the events of greater emergencies, the crew can return back to Earth, or have support delivered to them, within a matter of days instead of years. Stopping on the Moon lowers down the chances of failure on Mars, where mistakes could quickly prove more expensive than a thorough preparation on the Moon.

[5] Thomas Ormston, "Time Delay between Mars and Earth," August 5, 2012, https://blogs.esa.int/mex/2012/08/05/time-delay-between-mars-and-earth/.

The major technologies we will want to test is water extraction from the Lunar surface,[6] electrolysis conversion of water into hydrogen fuel,[7] crop production and maintenance of a sustainable greenhouse,[8] as well as 3D construction of radiation-proof habitats (titled Marshas, described in-depth in Phase 2) which we will use on Mars.[9]



A pre-visualization of Marscha's first 3D printing test on the Lunar surface in 2028.

Image compositing by Tomi Kufel, made from the AI SpaceFactory's rendering of a Mars-located Marscha.[10]

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[6] Julie Brisset, Thomas Miletich, and Philip Metzger, "Thermal Extraction of Water Ice from the Lunar Surface - A 3D Numerical Model," *Planetary and Space Science* 193 (November 2020): 105082, https://doi.org/10.1016/j.pss.2020.105082.
[7] Lishan Peng and Zidong Wei, "Catalyst Engineering for Electrochemical Energy Conversion from Water to Water: Water Electrolysis and the Hydrogen Fuel Cell," *Engineering* 6, no. 6 (June 2020): 653–79, https://doi.org/10.1016/j.eng.2019.07.028.
[8] Cyprien Verseux et al., "Sustainable Life Support on Mars – the Potential Roles of Cyanobacteria," *International Journal of Astrobiology* 15, no. 1 (January 2016): 65–92, https://doi.org/10.1017/S147355041500021X.
[9] AI SpaceFactory, "MARSHA by AI SpaceFactory," accessed April 10, 2021, https://www.aispacefactory.com/marsha.
[10] AI SpaceFactory, "AI SpaceFactory Mars Habitat Exterior Construction Progress," 2018, https://www.nasa.gov/directorates/spacetech/centennial_challenges/3DPHab/Ai-Spacefactory-image1.

Moreover, the Moon's low gravitational attraction, standing at about 1.62 m/s^2 (a contrast to 9.81 m/s^2 we experience on Earth), gives the opportunity to test our physical workout formula focused on maintaining astronauts' fitness levels and combat bone osteoporosis.[11] If our dietary specifications, fitness routines and exercise technologies (including small scale centrifuge workouts[12]) work effectively on a human test group on the Lunar surface, we will be able to warrant our first crew to Mars a proven regimen to stay healthy on the red planet (which actually offers a higher gravity than that of the Moon, with 3.71 m/s^2).

As water is present on both the Moon and Mars, we can prepare our technologies for viable and energy-efficient water extraction.[13] This will guarantee that our Mars missions will be able to successfully use extraction for hydrogen fuel and drinking water, ensuring safety, hydration, and sustainability of Martian settlements. This will also mean less water will have to be brought aboard rockets going to Mars for the manned missions.

The only technology that we will be unable to test on the Moon are the atmospheric extractors which will be used for oxygen generation on Mars. As the Moon has little to no atmosphere, this technology will have to be diligently tested in artificial environments on Earth before its first deployment on an extraterrestrial body.

Besides testing, we believe that with the setup of a Lunar infrastructure and various extraction technologies, we will be able expand the outpost into a mining and production facility.

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[11] Nadia H. Agha et al., "Exercise as a Countermeasure for Latent Viral Reactivation during Long Duration Space Flight," *The FASEB Journal* 34, no. 2 (February 2020): 2869–81, https://doi.org/10.1096/fj.201902327R; Babs R Soller et al., "Smart Medical Systems with Application to Nutrition and Fitness in Space," *Nutrition* 18, no. 10 (October 2002): 930–36, https://doi.org/10.1016/S0899-9007(02)00897-3.

[12] Alan R. Hargens, Roshmi Bhattacharya, and Suzanne M. Schneider, "Space Physiology VI: Exercise, Artificial Gravity, and Countermeasure Development for Prolonged Space Flight," *European Journal of Applied Physiology* 113, no. 9 (September 2013): 2183–92, https://doi.org/10.1007/s00421-012-2523-5.

[13] Roger N. Clark, "Detection of Adsorbed Water and Hydroxyl on the Moon," *Science* 326, no. 5952 (2009): 562–64, https://doi.org/10.1126/science.1178105; Anja Diez, "Liquid Water on Mars," *Science* 361, no. 6401 (2018): 448–49, https://doi.org/10.1126/science.aau1829.

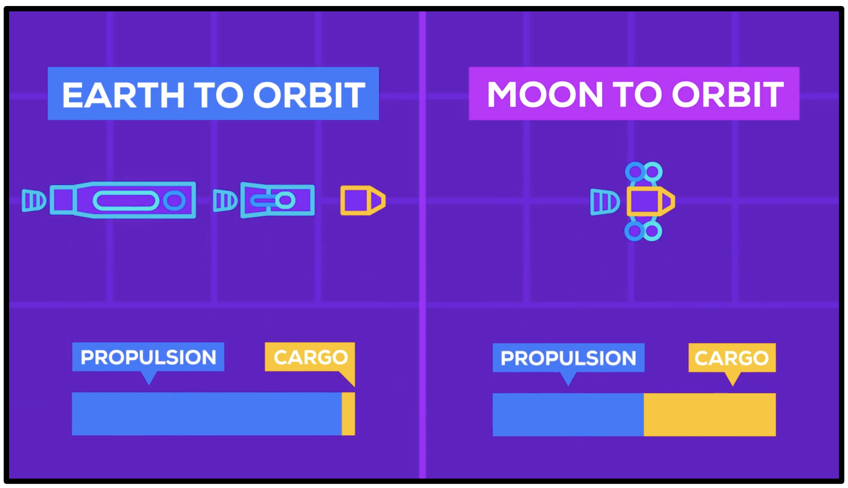
This will offer an incredible return on investment, capturing banks' and private investors' interests. Those resources will be used to supply our efforts to Mars and the future expansion of our extraterrestrial colony, as well as establish trade between the celestial bodies. In Phase 1, the transportation of cargo weight – from science experiments to contractor-specific resources – onboard return flights to Earth should be optimized financially in order to fully utilize the opportunity of rockets making back-and-forth voyages, whilst keeping return fuel costs to a minimum.

By focusing on the expansion of our facility with the fuel refining technologies, we can streamline the process of going to Mars by using the Moon as a temporary gateway to interplanetary colonization. One of the very reasons why launching from the Moon will be easier and more cost effective is it's significantly lower gravity. The next chapter will offer further insight into the benefit of this aspect, as well as look at the natural resources we hope to take advantage of on the Moon. Lastly, an overview of the Lunar outpost structures will offer a wholesome picture on the construction project.

The Lunar Gravity, Resources and Outpost Overview

by Tomi Kufel

Launching rockets from Earth poses a massive challenge. It is an engineering feat that requires a costly expenditure to tackle the immense power of Earth's gravity and reach outer space. With current propellant options, in order to launch things into orbit and overcome Earth's downward force, ~85% of a rocket needs to be fuel, leaving just ~15% for the integral structure of the rocket and payload. To reach an orbit of 'about 400 kilometers away from Earth, [the rocket] requires half of the total energy needed to go to the surface of Mars,' calculates Don Pettit, NASA's astronaut and chemical engineer.[14] All the cargo hiding under the fairings also has to be packed robustly, as the rocket is placed under great stresses and turbulence during its flight through Earth's atmosphere. In order to make Mars a reality, we need to take advantage of what is already out in space. Working hard to use up our resources and energy to fight Earth's gravity is inefficient and very expensive.



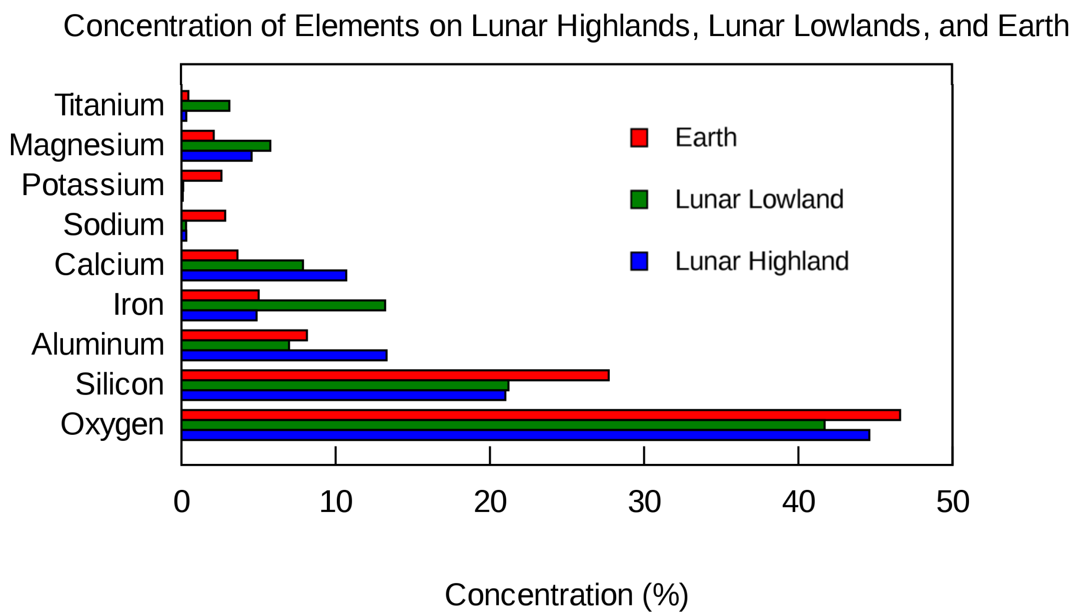
The ratio of propulsion to cargo is significantly more beneficial by launching from the Moon's orbit. This will cut down long-term shipping costs to Mars and make trade more viable with our future colony.[15]

In the long-term scope of our mission, with the resources we see necessary to bring with us to Mars, the Moon outpost will be a fruitful investment that will greatly help us lower down the total mission costs of making a Martian colony. The Moon not only offers cheaper launch costs, but also has plenty of natural resources we can strategically take advantage of.

Previous missions to the Moon, from the Apollo Program, to the American Lunar Reconnaissance Orbiter, and Chinese Yutu rover, have given us the opportunity to already study a lot about Moon's composition. This allows us to be more informed about what we can use, and

[14] Don Pettit, "NASA - The Tyranny of the Rocket Equation," January 5, 2012, https://www.nasa.gov/mission_pages/station/expeditions/expedition30/tryanny.html.
[15] Kurzgesagt – In a Nutshell, "How We Could Build a Moon Base – Space Colonization 1," September 16, 2018, https://www.youtube.com/watch?v=NtQkz0aRDe8.

what we can expect to ship to Mars. See Lunar surface concentration of elements on the bar graph below.



Element concentration of two Lunar terrain types in comparison to the Earth. Oxygen, silicon and aluminum parallel the concentration of elements we have on Earth. It is important to note that this data sample is biased towards the six Apollo landings which analyzed surface samples, many of which landed in the relatively safer lowland zones. Whilst different areas of the Moon ıy have different concentrations, the data still shows however, that it possesses valuable resources that can aid our space program. Bar graph by Roger Wilco,[16] based on data extracted from General Dynamics/Convair study under contract to NASA.[17]

What we are most interested in on the Moon is human life supply chemicals (like oxygen and water), rocket propellant (hydrogen and oxidizers) and construction resources (metals and concrete). Although eventually, other resources which are abundant in Lunar impact craters - such as titanium, platinum and gold - will also be beneficial to aid trade with Earth.

In close collaboration with Elon Musk's reusable space travel technology, we hope to use the currently developed SpaceX Starship to transport us to the surface of the Moon. We hope to

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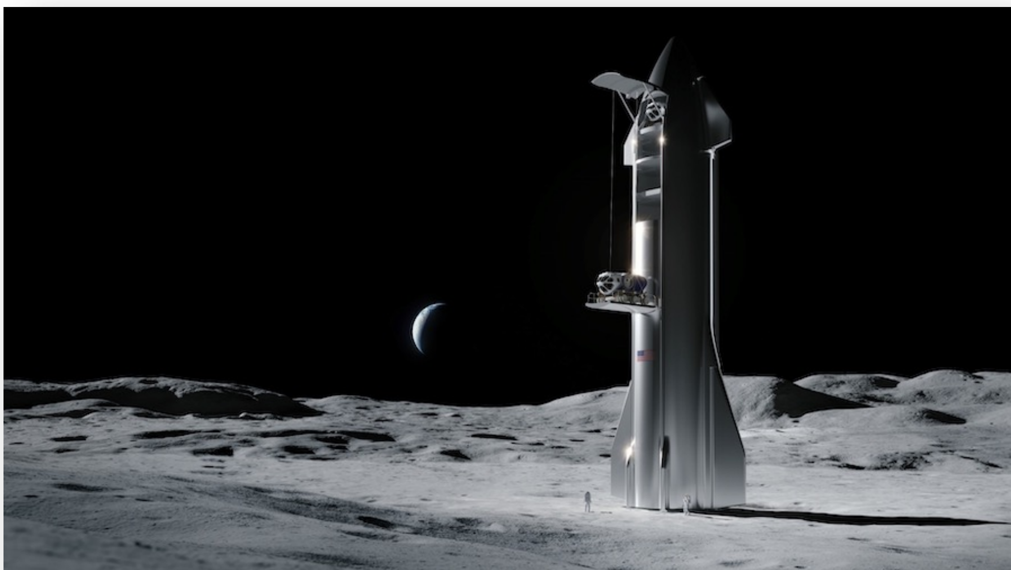
[16] Roger Wilco, "Relative Concentration of Various Important Elements on Lunar Highlands, Lunar Lowlands, and Earth.," July 8, 2010, https://en.wikipedia.org/wiki/File:Moon_vs_earth_composition.svg.
[17] Mark Prado, "Lunar Materials - Apollo/Luna," 2002, https://www.permanent.com/l-apollo.htm.

start off by shipping various technologies for testing, as well as a group of robot fabricators to take care of the manual labor required to construct the necessary infrastructure.

To our luck, Lunar regolith has the perfect composition to make concrete. Our team of versatile autonomous 3D printing fabricators made by innovative Eckersley O'Callaghan company solutions (discussed further in "Supply Mission to Mars" chapter**),** will start construction efforts in 2024.[18]



The first Starship to land with our team of versatile robots, which will begin construction of the Lunar Outpost in 2024.[19]

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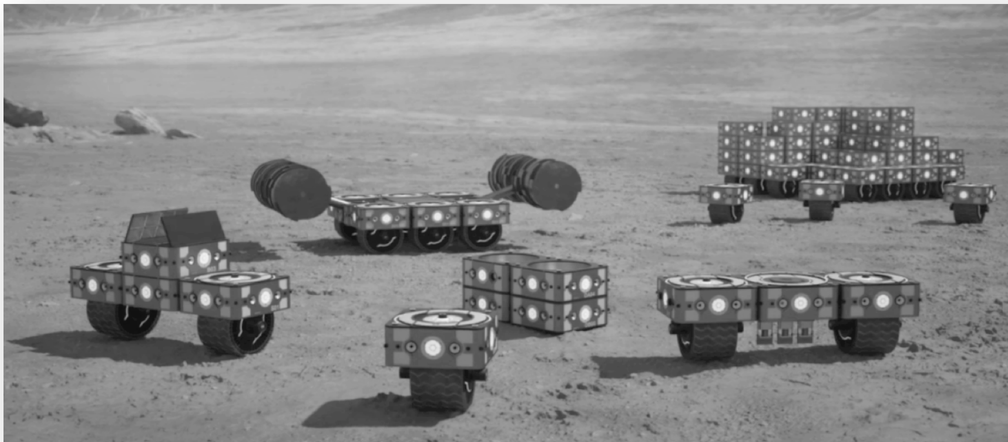
[18] De Kestelier Xavier et al., "Hassell | NASA 3D Printed Habitat Challenge," Hassell, 2018, https://www.hassellstudio.com/project/nasa-3d-printed-habitat-challenge.
[19] SpaceX, "Starship Lunar Landing at Moon Base Alpha."



A team of our autonomous robots made by Hassel and Eckersley O'Callaghan, smiling and ready to get building on the Lunar surface.[20]

The construction efforts will also help to jump start the production of other fabricators that would allow for an exponential production of Lunar robots built out of Moon itself.[21]

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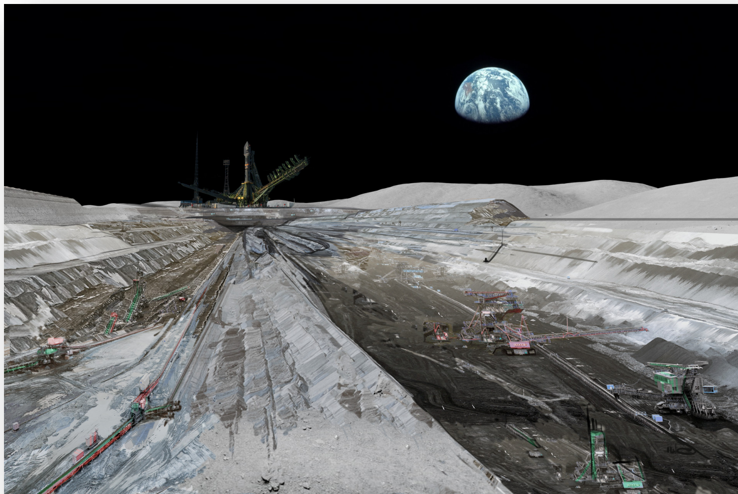
[20] HASSELL, "HASSELL + EOC Presents MARS HABITAT," March 13, 2019, https://www.youtube.com/watch?v=AIrH01N9AsE.
[21] NASA, "NASA's Fith Annual Robotic Mining Operation," March 27, 2013, https://no.pinterest.com/pin/156922368238642589/.



An example of in-situ resource collection on the Lunar surface

after a few years of outpost expansion.[22]

In overview, our Lunar outpost will include various task-specific structures, which would simply be too massive to be brought with us from Earth.[23]

- Resource Mine: resources like metal and regolith could be first refined on a small-scale using a repurposed refinery robot. Later, these refined resources would help set up larger refinery and mining structures (such as illustrated above).

- Water Extractor and Purifier: water extractor at the polar caps, which would melt and purify the molecules using solar energy and radiation. The water will be used to test hydrogen extraction technology. It will also supply the outpost and future missions with drinkable Lunar water, maintaining hydration of our astronaut crews.

[22] William A. Ambrose and Artstation, "Return to the Moon: Resources, Risks, and Rewards," May 20, 2019, http://www.searchanddiscovery.com/documents/2019/42413ambrose/ndx_ambrose.pdf.
[23] Cory Zapatka, "Building a Lunar Base out of Moon Dust," September 18, 2018, https://www.youtube.com/watch?v=j0TPJQSmAHU.

- Robot and Components Factory: the hub for all construction, where more robots could be made, as well as receive necessary maintenance.

- Nuclear Reactor: which would use Helium3 present on the Moon,[24] an isotope which the Chinese Lunar Exploration Program is currently underway on patenting for our mission. This would help us get the necessary energy to conduct electrolysis of splitting water molecules into hydrogen and oxygen, as well as powering up all robotics and machinery.

- A Fuel Refinery: making hydrogen fuel made from water using electrolysis.

- A Refueling Station: equipped with storage tanks offering refueling ports.

- A Rocket Launch Pad: will offer stable landing for incoming rockets, and launch point for rockets going to Mars. This will help minimize soil digging that can occur when the engine fires into bare surface during takeoff.

Alongside these developments, we hope to establish various laboratories and test-habitats. These will collect more data to guide us on our missions, suggest new alternatives to improve and course-correct our plans, as well as prepare us for future deployment on Mars. The Lunar outpost will rotate astronaut crew for short- and long-term durations (up to two years), and test our capabilities for keeping astronauts healthy; from overcoming challenges such as bone osteoporosis, radiation exposure, and various psychological factors that play a role in human space missions.

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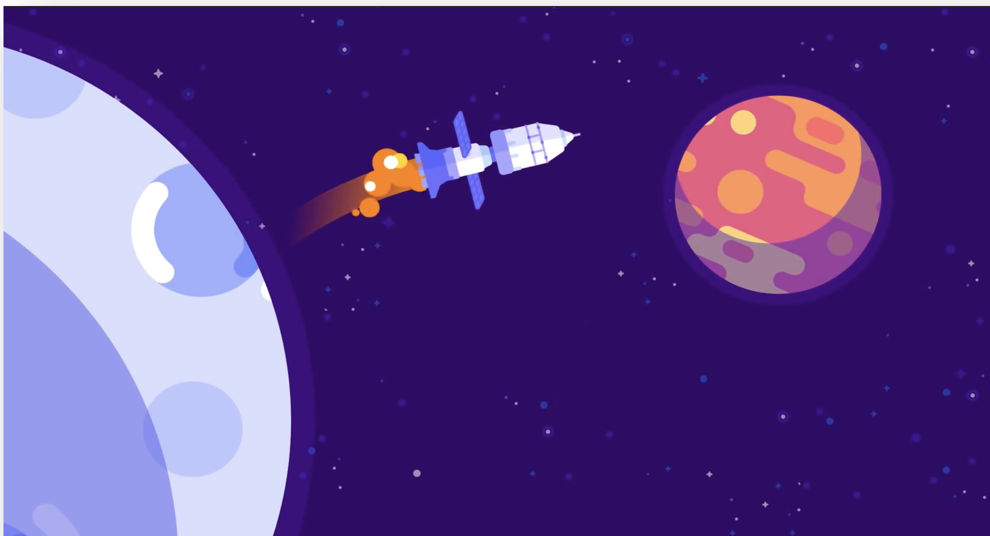
[24] Adrian Berry, "How China Is Sending Man Back to the Moon to Mine Safe Nuclear Power and Become the World's Energy Giant," February 29, 2016, https://www.telegraph.co.uk/news/science/space/nightsky/12178122/night-sky-march-2016-china-space-mission.html; The European Space Agency, "Helium-3 Mining on the Lunar Surface," accessed April 23, 2020, https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Space_for_Earth/Energy/Helium-3_mining_on_the_lunar_surface.



From this point onwards, we are ready to launch our first supply mission to Mars.[25]

[25] Kurzgesagt – In a Nutshell, "How We Could Build a Moon Base – Space Colonization 1."

| Supply Mission to Mars |

Launch Vehicles

by Mason Friesch

The type of propulsion system that we will use to send the supplies prior to any human mission is the solar electric propulsion (SEP). This type of propulsion is a combination of solar cells and electric thrusters to propel a spacecraft through outer space. This type of technology has been used before by various space agencies but never on this large of a scale. We wanted to use this particular propulsion specifically for our cargo missions for a couple reasons. First, this type of propulsion needs far less fuel than regular propulsion systems. Because this rocket does not need as much fuel, there is extra weight available for more supplies. Some of these supplies that we will bring will include a GPS satellite system, 20 AI robots, an oxygen extractor, and Marsha 3D Printers. These are just an example of the most important supplies that will be sent to the planet before any humans arrive. This propulsion system allows all of these supplies to be able to fit on one or maybe even two supply missions. The only potential con of this type of propulsion system is that length of the journey. But for our case, because we are only using this propulsion to send the supplies without crew, the length does not matter. We are able to send these supply missions months or even years in advance to the human missions. Also the supplies will not get damaged for being in space for a longer period of time. Overall, we think SEP would be the best and most cost efficient way to send our supplies beforehand in order for everything to be ready for humans when they get to Mars.

Landing and Location

by Mason Friesch

The landing location for our mission will be on the plains of Arcadia Planitia**.** This location is currently a favorite among both SpaceX and NASA. This location would be the best for a few reasons. First, there are ample ice deposits right under the surface.[26] Current readings of the surface show that this ice could lie within a foot or even an inch of the surface. Potentially, astronauts would not need heavy equipment to dig up the ice, they could just use shovels or other hand tools. This is extremely beneficial as water is one of, if not the most, important resource for human survival on Mars. Another reason for Arcadia Planitia is the location relative to the equator. Scientists believe that a location closer to the equator is more beneficial for the astronauts. At the equator, there are warmer temperatures and a better balance of day and night. This balance between day and night is very important because of our need for solar power. Some of the technology used by the astronauts will need to be solar powered so there needs to be sunlight. This is why it is extremely difficult to land on the poles of Mars. The poles could potentially be dark for months at a time. This would basically eliminate any possibility of using solar power. Also, astronauts need to live in an area with sunlight. There could potentially be a large psychological toll on the astronauts if they don't see light for months at a time. Finally, the last reason that Arcadia Planitia is the most beneficial spot for humans to land is when humans want to send rockets back to Earth, it is easier to do that from a location closer to the equator. This is because the planet spins the fastest at the equator so astronauts would need less fuel to launch their rockets.

[26] Ali M. Bramson et al., "Widespread Excess Ice in Arcadia Planitia, Mars," *Geophysical Research Letters* 42, no. 16 (August 28, 2015): 6566–74, https://doi.org/10.1002/2015GL064844.

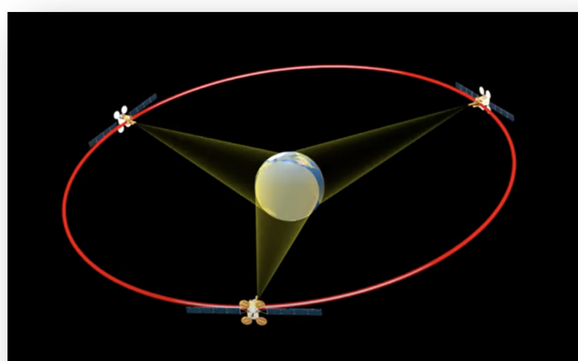
The best technique for landing the supplies on Mars would be similar to the process of landing NASA's InSight spacecraft.[27] First, the supplies would separate from the solar panel array that was used to power it through space. Next, the supplies will drop and enter the atmosphere at high speed. The next step is releasing a very large parachute that will significantly slow down the drop speed of the supply module. Next the heat shield will drop off as temperatures stabilize. As it continues to descend with the parachute still attached, module will deploy its legs like landing gear. Then, the parachute will detach and rockets that are attached to the module will fire, allowing the module to slow down and reach safe speed for surface contact. The supply module will then land on the Martian surface and the robots will be deployed to commence labor.

Technology Brought to Mars

Martian Interplanetary Communications and GPS System
by Tomi Kufel

Upon approaching the Martian gravitational sphere of influence, the modified Starship will release a network of three satellites into an areostationary orbit (analogous to Earth's geostationary orbit) that will allow for interplanetary communication.[28] These will orbit at about 13 600 km above the Martian surface.

Three geo-stationary satellites coordinated into an equilateral triangle formation will be enough to cover all sides of the Martian landscape, as well as maintained a fixed position relative to the surface of Mars.[29]



[27] NASA, "Entry, Descent, and Landing | Landing," NASA's InSight Mars Lander, accessed April 28, 2020, https://mars.nasa.gov/insight/timeline/landing/entry-descent-landing.
[28] Mars One, "Communications System - The Technology," Mars One, 2020, ." https://www.mars-one.com/technology/communications-system/.
[29] Matthew Sabin, "How Do Satellites Work? | ICT #10," July 31, 2019, https://www.youtube.com/watch?v=ror4P1UAv_g.

These satellites will be equipped with transponders, reception antennas, batteries (to keep the satellite powered on the dark side of Mars), and solar panels that will be large enough to power the satellite up entirely using the sun's energy (which will have to account for the reduced solar energy reception due to Mars' further distance from the Sun). Another important element to consider will be corrector thrusters to keep the orbit of the satellites in check. These thrusters will activate when the satellite's orbital trajectory is affected due to Mars' non-spherical shape (which deviates even more from an ideal sphere than Earth does).[30]

The interplanetary satellite system would allow for data bandwidth capable of relaying communication, images, and other information from the Mars surface, to its orbit, and back to Earth.

Besides receiving and relaying data from the Martian surface to Earth and vice versa, we also want to deploy a network of Global Position System (GPS) satellites that will allow for minimal trilateration over the area around Arcadia Planitia. Using three satellites only, the on-surface GPS systems built into rovers and rockets will require a precise atomic clock, otherwise the time dilation between the device and satellites can off-set the calculation for triangulating the location. Overtime, we hope to ensure that at least 4 GPS satellites will be established over our colony area, and eventually add even more satellites in the future Phase 3 of our mission. This increased network will ensure a high enough density of satellites to establish wireless connection all around the Martian globe for new colony locations and exploration missions. For the GPS satellite itself, we will be using Lockheed Martin's 3.0 GPS "Vespucci" for top precision and

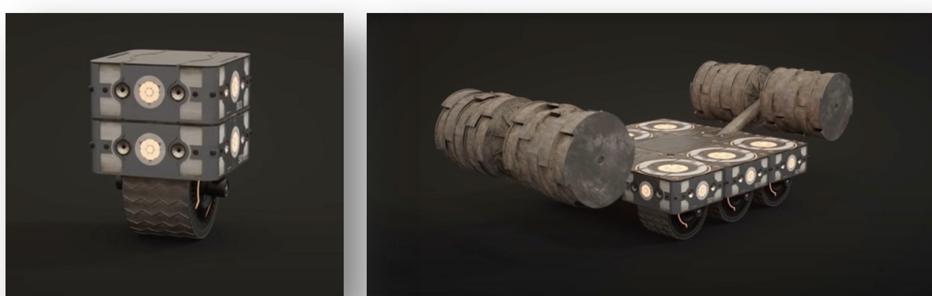
[30] Emily Lakdawalla, "Stationkeeping in Mars Orbit," The Planetary Society, June 27, 2013, https://www.planetary.org/articles/stationkeeping-in-mars-orbit.

accuracy.[31] This will help navigating not only exploration on Mars via land vehicles, but also navigate the trajectory of our rockets during descent and ascent.

In order to maintain stable connection between Earth Control Center and Mars over the years, and avoid interference from the sun, later satellites will also be set up at Sun-Mars Lagrange points, that would maintain the course in the Martian Orbit, and remain fixed in view of both Mars and Earth in the periods of solar occlusion. These satellites would function as pass-on relay devices, that would pick up the signals from the Martian areostationary satellites, and assist with relaying them to Earth.

20 Multi-Functional Robots
by Federico Zampedri

A fleet of around 20 robots will be released on the surface of Mars. These robots will start 3D printing, using Martian Regolith, to create the overground cave system where the inflatable Command Center will be stored. After the cave is complete, the robots will be assigned new tasks such as scouting new locations, digging Martian regolith, and other tasks to create a self-sustaining environment.



Versatile robot designs made by Hassel and Eckersley O'Callaghan.[32]

[31] CBS, "New Generation of GPS Satellites Launching," December 18, 2018, https://www.youtube.com/watch?v=iShK3QubGWs; Mike Wall, "SpaceX Launches Super-Accurate Next-Gen GPS Satellite for US Air Force," Space.com, December 23, 2018, https://www.space.com/42774-spacex-launches-next-gen-gps-satellite.html.
[32] HASSELL, "HASSELL + EOC Presents MARS HABITAT."

Oxygen Extractor
by Tomi Kufel

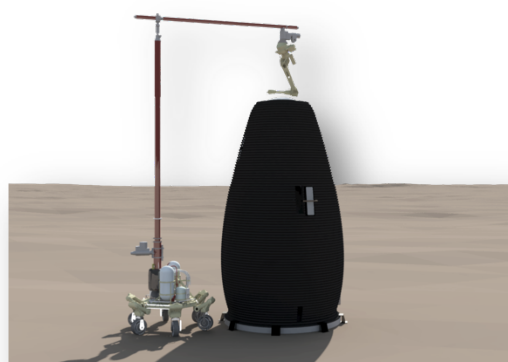
The Martian atmosphere is one of the challenges we will be overcoming on Mars, and thus an oxygen extractor is paramount to our success. An oxygen extractor is currently in development for us, constructed in partnership with NASA. We are planning the technology will be long proven for human support and ready for launch in 2033.

MOXIE is one such device currently in testing. We are hoping to build larger sized versions which will be launched to Mars during the supply drop.[33]

Marsha 3D Printers
by Federico Zampedri

The Marsha 3D printers will be the designated printers designed to print the Marsha habitat. These printers will be sent with the supply mission so when the first crew arrives they will be able to start printing the houses without having to wait for another supply mission.

A 3D-rendering of a versatile printer arm completing construction of a single Marsha unit.[34]



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[33] Asad Aboobaker, "NASA's Gold Box Will Make Oxygen on Mars," March 29, 2020, https://www.youtube.com/watch?v=UkQHCSZQvv0.
[34] AI SpaceFactory, "MARSHA by AI SpaceFactory."

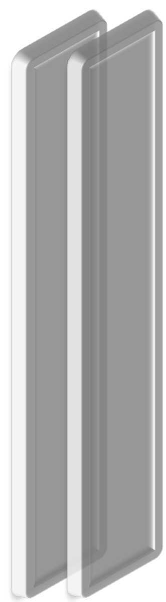
| Phase 1 Recap |

by Tomi Kufel

To ensure the longevity of our Martian colony and sustained expansion in its first century, we believe an outpost on the Moon is not only beneficial, but necessary. In short, the Moon is the perfect prequel to our Mars Colony. **Phase 1** makes our overarching space program more realistic to achieve by using the Lunar surface as a testing ground. This will increase the safety of our Mars mission, and minimize mission-risks. The unmanned supply drop allows us to cut down on costs of the many resources required for human maintenance during transit by taking advantage of A.I. and remote control. In turn, by relying on software and robotics for the supply drop on Mars, we maximize the cargo space for bringing the necessary materials and technologies that will become the building blocks for the first Martian settlements.

We schedule the completion of this phase by the year 2035. From this point onwards, we are ready to tackle new challenges as we proceed into Phase 2 of our program.

Phase 2

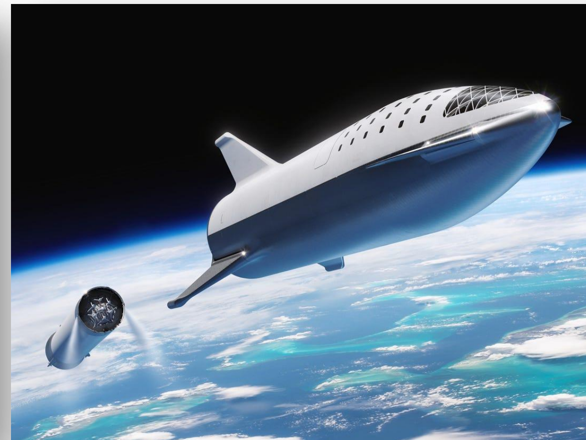


'It might be helpful to realize, that very probably the parents of the first native-born Martians are alive today.'
— Harrison H. Schmitt, NASA Astronaut.[35]

[35] New Mexico Museum of Space History, "Harrison H. Schmitt," *New Mexico Museum of Space History* (blog), 2021, https://www.nmspacemuseum.org/inductee/harrison-h-schmitt/.

| Phase 2 Introduction |

by Federico Zampedri



The technology behind SpaceX's interplanetary transport system currently being developed will lay the fundaments for constructing our spaceships to Mars.[36]

In **Phase 2** of our mission we plan on selecting the crew of astronauts and provide them with the specific training needed for the Mars mission. The selection and training will be happening concurrently over the years with the Phase 1 developments on the Moon and preparation of the unmanned supply mission. Once the astronaut training is over, the first manned mission to Mars will take off with a nuclear propulsion rocket in 2035. Many resources will be already in place from our supply mission. Once landed on the Martian surface, the astronauts will house in an inflatable habitat which then will be turned into the command center. Once the astronauts have settled, our home building process will start. The crew will start planning where to build the Marsha houses, and instruct the Marsha 3D printers to start printing. The astronauts will also start to take advantage of the environment such as the Martian soil for growing plants, but also to extract

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[36] SpaceX, "SpaceX Interplanetary Transport System," September 27, 2016, https://www.youtube.com/watch?v=0qo78R_yYFA; SpaceX, "SpaceX's next Generation Vehicle," September 18, 2018, https://www.instagram.com/p/Bn2WWTYFxmY/.

water from it. The astronauts will also set up an oxygen extractor so they will have a secure supply of oxygen. In Phase 2 the astronauts will build a small self-sustaining outpost on the Martian Surface setting up the basis to expand.

| Astronaut Selection |

by Kara Reiss

Astronaut Criteria

Astronaut application requirements (These are the NASA requirements):

1. A bachelor's degree in engineering, mathematics, biology, physical science, or computer science
2. 3 years of related professional experience
3. Pass physical test
4. 20/20 vision

Once astronauts pass the application process they will move on to the second round of tests to see how compatible they are with being in space. These tests will evaluate their skills as a team player, their problem solving skills, and how well they do under physical and mental pressure. As trials and testing continue, we will hand select people who best fit our ideal astronauts. From here we will be able to select a team of astronauts that we think will best work together.

Ideal Space Crew and Why

The crew will be made up people who can focus on the three main goals of the mission: A safe voyage (related to the takeoff, landing and interspace travel) is one. The second is concerned with the initial colonization of Mars, including setting up living and storage structures, establishing food crops, establishing water sources, establishing energy sources, setting up the waste facility. The third group will have a health and wellbeing focus, which will include two people from the voyage mission (pilot and secondary pilot) later to assume roles as safety and security personnel and medical individuals who will ensure the wellbeing of all the crew. 10 (ten) original astronauts will make up the crew.

- **1 Mission Commander:** This person will be in charge of the overall mission including both the flight and the colonization of Mars. This person would be responsible for making sure everything goes according to plan. They are to deal with any problems that might arise and give orders to other members of the crew.
- **1 Main Pilot/Security**: This person will be in charge of flying the spacecraft to and from Mars. They will also be in charge of making sure that landing the spaceship goes well. Once on Mars, they will assume a security of the crew responsibility.
- **1 Secondary Pilot/Security:** We think it is important to have a secondary pilot, just in case anything happens to the main pilot. This person will help in assisting the main pilot fly the space craft. Once on Mars, they will assume a security of the crew responsibility.
- **2 Doctors** - one in general medical issues, the second specializing in psychology: having medical staff is extremely important to our missions, because we need to make sure everyone stays healthy for the long and dangerous journey. We have decided to include 2 doctors, because we need to make sure that in case something happens to one of them, we will have a backup care physician. It is also useful to have two doctors, because one can focus on psychological problems while the other focuses on physical problems.

- **3 Engineers :**
  - 1 Structural Engineers - Shelter, storage, waste facility. This person will oversee the building of living structures, storage structures and the waste facility.
  - 1 Energy Engineer - Setting up renewable energy will also be key and thus this person will need to first set up Solar Energy as well as establish sources for future energy, including propellants.
  - 1 Communications and Electrical Engineer - This person will be tasked with setting up all the electrical and communication equipment related to the structures on Mars. Setting up and maintaining solid communications with Earth will be paramount to his/her role.
- **2 Scientists:**
  - 1 Food Scientist: It is important to have a botanist, so when we arrive on Mars we will have someone who can start farming. Farming will be extremely important because we will need to try and be as self sufficient on mars as possible.
  - 1 Hydrologist Scientist: Water production on Mars will be key to long term survival. Their job will be to set up an initial water production facility and storage and then to conduct planet wide scans for potential water sources.

Crew Cohesiveness

Team cohesion is an important element of a successful mission. We need to select astronauts that can have good team cohesion. Three primary characteristics that define team cohesion are interpersonal attraction, focused on the same goal, and group pride. During training, we will have specific people looking for flaws in the relationships between the crew members. This is especially important when the crew is placed under severe stress during training. They will have to see who can continue to work well with others even in extremely stressful environments. It has been reported that accidents that occurred on prior space shuttle missions were related to poor team cohesion. Things we will look out for are breakdowns in communications, poor team coordination, role conflicts, and interpersonal conflicts.

Preparation

It is very important to the success of the mission that the crew works well together and that they have good group chemistry. In preparation for the mission, the crew will have to spend countless hours working and bonding together to insure their compatibility. To prepare for Mars we will have to put our astronauts through several simulations to prepare for problems that might arise.

| The First Explorers |

Mission Tasks

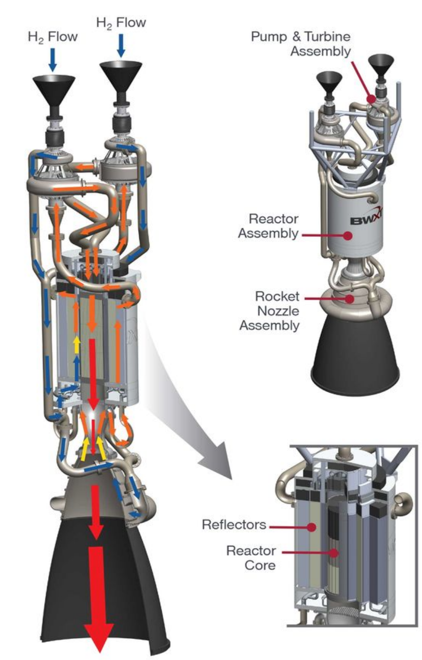
by Kara Reiss

Our mission for our first explorers is for them to stay on the surface of Mars for 2 years and for them to start building the foundations for more people to come and live on Mars. After 2 years of being on Mars we hope to complete the construction of a launchpad, 25 Marshas, a mining center, and a SuperInflatable structure that houses the oxygen tanks module, a research center module, a laboratory module, a medical bay module, a greenhouse module, and a common area/living space for the astronauts. All these structures will be necessary to build a self-sustaining colony on Mars.

Launch/Transit

by Mason Friesch

The type of rocket that we will use to carry our initial 10 astronauts will be based on the SpaceX Starship rocket technology. The biggest change we intend to make to the rocket is it's propulsion system. We want to use a Nuclear thermal electric propulsion system. This would be the best propulsion system for getting to Mars quickly and relatively safe. The engine would have a small nuclear reactor to generate heat from uranium fuel. This heat that is generated will be transferred to a liquid propellant, like liquid hydrogen, which will expand into a gas and get shot out through a nozzle to produce the thrust. Nuclear rocket propulsion is extremely powerful. According to researchers, this type of propulsion system can get transit time down to about 3 months.[37] This would be huge for Mars travel. This would mean that astronauts are in space for less time which means physical effects such as lack of gravity and solar radiation will not impact their bodies as much. Also, with lower transit times, there is a larger window for us to launch spacecraft to Mars. With chemical rockets, there is only a 30 day window roughly every 2 years. Nuclear propulsion would allow this window to be open for longer which can allow us to send ships more frequently. Another quality that is unique to nuclear propulsion is the ability for the astronauts to abort the mission a couple months in if there is some kind of failure. This is because nuclear propulsion burns at a slower rate than chemical propulsion so there will be more



[37] Fraser Cain, "Earth to Mars in 100 Days: The Power of Nuclear Rockets," July 1, 2019, https://phys.org/news/2019-07-earth-mars-days-power-nuclear.html.

fuel leftover after launch. This is impossible for a chemical propulsion system as it burns fuel so quickly that there is only enough fuel leftover to barely get back to Earth from Mars, much less turn around mid-flight.

Another potential benefit of nuclear propulsion is that we could, potentially, use one of the small nuclear reactors from the engine to power our habitat. If we could find a way to get the reactor off the ship and set up close to our habitat, then it could power a lot, if not the majority, of the habitat structures.

Transit Vehicle

by Mason Friesch

The transit vehicle for our initial launch of astronauts will be most similar to the SpaceX Starship. We feel this is most similar to Elon Musk's vision of the first mission to space as we want to follow his vision. This ship is also the most suitable for the journey. This is thought to be able to hold about 100 tons of payload. This means the starship can easily take 10 astronauts to Mars along with whatever else is needed. For a journey to Mars, there needs to be a lot of supplies not only for survival on Mars, but for survival during space flight. The spaceship gives us the capabilities to carry everything we would need for long term space travel and a long term stay on Mars. This large payload capacity also allows us to bring our inflatable command center habitat with our initial astronauts. This is extremely important as this is where our initial astronauts will spend most of their time.

Reusable Starship models are currently undergoing high-altitude flight testing by SpaceX.[38]

Another transit vehicle that we are interested in using for the future (for which we don't have the technology yet at this time), would be a rotating spacecraft with a centrifuge, similar to the one presented in *The Martian* (2015).[39] As this technology is in the more distant future, we do not yet have many details on the feasibility of this construction. Nonetheless, we believe such concept offers a realistic solution to creating artificial gravity in space. A space craft with side arms rotating optimized to rotate at the right speed around the center would generate centripetal forces that would help in maintaining the physical health of a manned crew . Our goal would be to have a spacecraft like this permanently orbiting around Mars, similar to NASA's concept for the Lunar gateway. This spinning craft would be able to carry hundreds of Martian colonists aboard as we begin to build a new colony on Mars. A spacecraft like this would need to be developed before we start colonizing Mars as our normal rockets will not be able to carry as many people.

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[38] SpaceX, "Starship SN8," November 25, 2020, https://www.spacex.com/vehicles/starship/.
[39] Ridley Scott, *The Martian*, science-fiction (20th Century Fox, 2015).

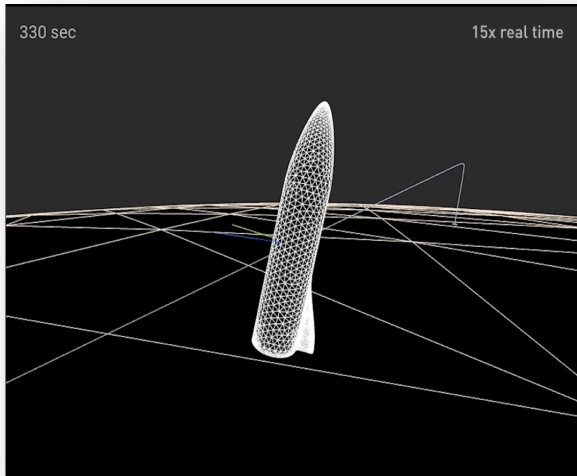
Landing on Mars

by Tomi Kufel

Contrary to the almost non-existent exosphere of the Moon, Mars does have various gases to make up for an atmosphere worth considering. However, Mars's atmosphere is significantly less concentrated than that of Earths; about *100 times* thinner. Whilst the standard pressure on Earth is about 1 013 millibars at sea-level, the average pressure on Martian surface is just 6.5 millibars. The pressures of course vary with altitude, ranging between 0.7 and 14 millibars at its lowest and highest surface points.[40]

Whilst atmospheric entry can pose concern for durability of the descending spacecraft, our Starship will have the durability to use the aerodynamic drag to its advantage. Whilst the atmosphere is thinner than that of Earth, air drag can still help to naturally decelerate landing craft. According to SpaceX, the plan is to reduce 99% of the ship's energy purely by aerodynamic maneuvers; or more precisely, slow down the ship by over 6 km/s (down from 7.5 km/s upon entry). SpaceX Starship will work as our reusable descent vehicle. It will be able to enter the atmosphere at a high speed of 7.5 km/s from orbit, and use the atmospheric drag to slow itself down. To increase the aerodynamic coefficient during descent and protect the rocket from heating, the Starship would have to use flaps and thruster control to orient itself to an attack angle pointing with its ablative heat shield.[41]

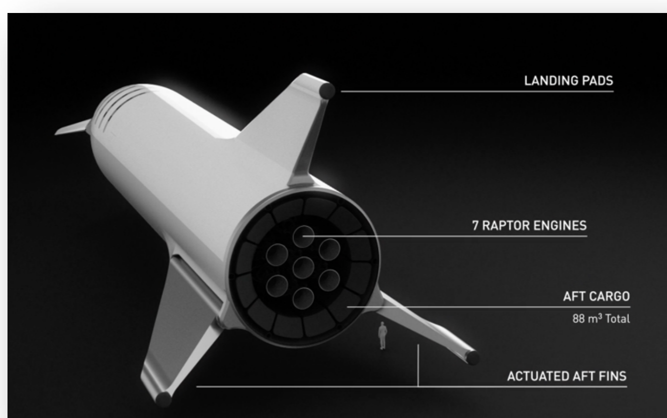
[40] Arizona State University, "Mars Education | Atmosphere," accessed April 13, 2020, https://marsed.asu.edu/mep/atmosphere.
[41] SpaceX, "Vehicle Landing Process - Starship Simulation," October 14, 2017, https://www.youtube.com/watch?v=5seefpjMQJI.



The frame above is taken from SpaceX's computer simulation, and shows the necessary orientation of the Starship as it enters the Martian atmosphere.[42]

The ship's aerodynamic design and its actuated aft fins will be critical in maintaining the safe orientation of the spacecraft this way during atmospheric entry This will circumvent the issue of having the ship fly too fast through the atmosphere pointing with its nose-cone, and avoid exposing the unshielded hull to heat damage. The crew is estimated to face a peak of 5g (49 m/s²) during the deceleration maneuver.[43]

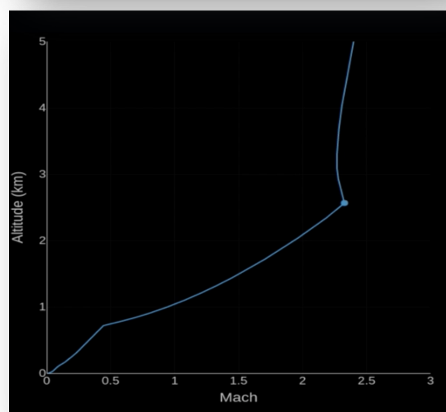
The starship design with annotated ship components. The functionality of the landing pads, engines and aerodynamic fins are critical to landing.[44]



[42] SpaceX.
[43] "Mars - SpaceX." 17 Sep. 2018, https://www.spacex.com/mars. Accessed 8 Apr. 2020.
[44] Space Models, "SpaceX BFR Ship | Aft Fins Mechanism," November 3, 2018, https://www.youtube.com/watch?v=jxP-G8Fv2L0.

After the natural aerodynamic drag slows down our vehicle to about 0.8 km/s (2.4 Mach), seven raptor engines will activate at the height of approximately 2.5 km above the surface, and adjust thrust during final descent for a smooth landing.[45]

The altitude versus speed graph during the descent of SpaceX Starship vehicle on Mars.[46]



The Starship after successful touchdown on the plains of Arcadia Planitia.[47]

After touchdown, we are ready to experience the historic moment: first human step on Mars. Following the celebration of this milestone, the crew will proceed with the construction of our second home.

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[45] SpaceX, "Interplanetary Transport System," September 27, 2016, https://www.youtube.com/watch?v=0qo78R_yYFA.
[46] SpaceX, "Vehicle Landing Process - Starship Simulation."
[47] SpaceX, "Starship Craft Landing on Mars," September 1, 2019, https://www.geekwire.com/2019/nasa-checks-spacexs-potential-starship-landing-sites-mars-water-mind/.

| Creating the Second Home |

The Command Center

by Federico Zampedri

For our command center we plan on using the Habitat Concept made by Hassel.[48] This habitat would consist of creating 3D printed caves using the Martian regolith. The cave would be built by small modular robots who will be able to gather the Martian regolith and melt it to create a viscous material that can be used to 3D print. These robots are made to combine with each other to create larger robots with different functionalities such as 3D printing or digging up the regolith. If one robot breaks down, it can easily be replaced by another one. The cave structure would be built before the astronauts arrive. The cave structure is designed to be thick enough to protect the habitat from the radiations present on the surface but still have open areas on the sides so the astronauts will be able to see outside. Then when the astronauts arrive, they would bring the habitat structure with them. The habitat is an inflatable and collapsible structure which will provide a safe environment for the astronauts. The command center will also be attached to the oxygen extractor, so the habitat will have the oxygen needed for the astronauts to live. The power will be provided by a solar farm and two kilo nuclear power reactor brought with the habitat. The Control Center will be the place where the astronauts will live in the beginning of the mission.

The control center will have different modules as seen below.

- A living quarter, the first living room on Mars where astronauts will hang out and pass time together.
- A laboratory where the crew can analyze soil samples and rocks. And a workshop module, where the crew will be able to 3D print parts that they need and fix whatever is broken.
- A greenhouse module, where the crew will be able to grow some of the food that they will eat during the mission.

[48] Xavier et al., “Hassell | NASA 3D Printed Habitat Challenge.”

- A storage and a medical bay module.
- A temporary private living quarter module with a small gym for the astronauts to exercise their muscles and not suffer from bone loss and muscle loss.
- The Control Center will also have the space suits attachments, so the astronauts will never have to enter the habitat with space suits. This will help us avoid fine electrostatically charged Mars dust that contains toxic perchlorate salts would contaminate the interior of the habitat, and threaten the health of the crew.[49] Air quality control and ventilation measures will still have to be put in place to keep interior atmosphere hazard-free.

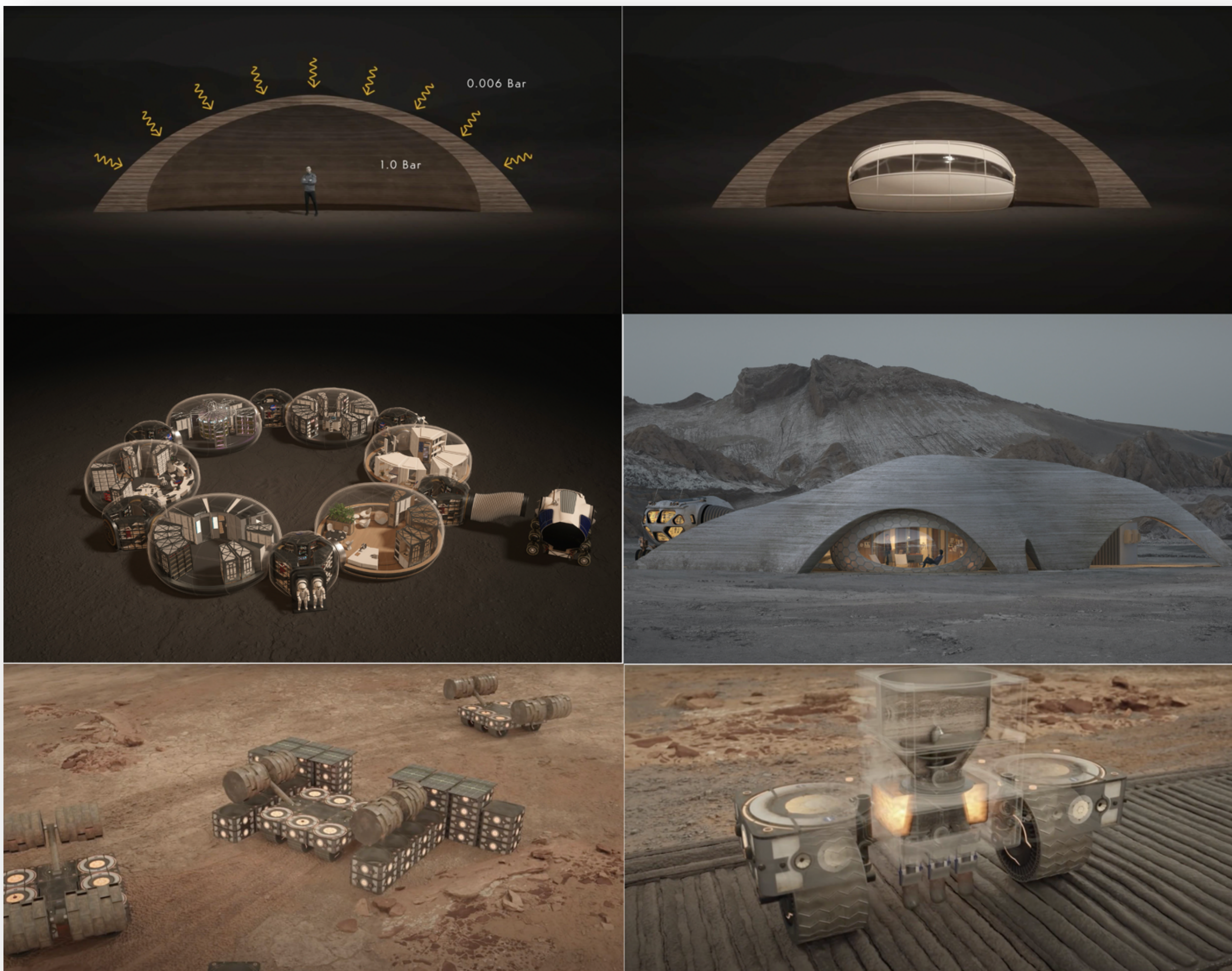


Image renderings of various technologies to be deployed on Mars.[50]

[49] Kurzgesagt, "Building a Marsbase," February 3, 2019, https://www.youtube.com/watch?v=uqKGREZs6-w.
[50] Xavier et al., "Hassell | NASA 3D Printed Habitat Challenge."

Exploration of the Martian Territory

by Federico Zampedri

The robots who built the structure for the command center will be reassigned to go and scout the Martian territory. Each robot is equipped with an ultrasonic scanner to analyze the Martian regolith and provide data to the command center.

Second, with a future resupply mission, a rover similar to the Lunar Rover designed by JAXA and Toyota will be brought to the Martian surface for longer exploration missions. The JAXA inspired rover will be made to tackle the Martian terrain with appropriate wheels. One of the main features will be the pressurized cabin that will be able to directly attach to the control center, and later the Marsha houses, to prevent the astronauts from having to exit the habitats in a spacesuit and having to enter the rover in spacesuits. With this attachment feature, Martian regolith which contains perchlorate, a toxic chemical for humans, will not be able to enter the habitat or the interior of the rover.[51]

[51] Leonard David, "Toxic Mars: Astronauts Must Deal with Perchlorate," June 13, 2013, https://www.space.com/21554-mars-toxic-perchlorate-chemicals.html; Kurzgesagt, "Building a Marsbase."

Using In Situ Resources

by Tomi Kufel and Federico Zampedri

The Advanced Plant Habitat

The Advanced Plant Habitat is a mini fridge sized growth chamber to grow small plants into space.[52] This Advanced Plant Habitat is able to control the temperature, the oxygen and carbon dioxide levels. The system can be adjusted to adapt to the needs of different plants. The Advanced Plant Habitat can control all the levels autonomously, the only human action needed is to add water to the tank, and change filters such as the ethylene scrubber and carbon dioxide scrubber.

For our mission, we would like to take this Advanced Plant Habitat and create a larger version of it so more crops can grow in it. This would be used in the first part of the mission to supplement the food brought from earth by the astronauts. While the astronauts are taking advantage of the Advanced Plant Habitat they would start planting more and more crops to become sustainable.

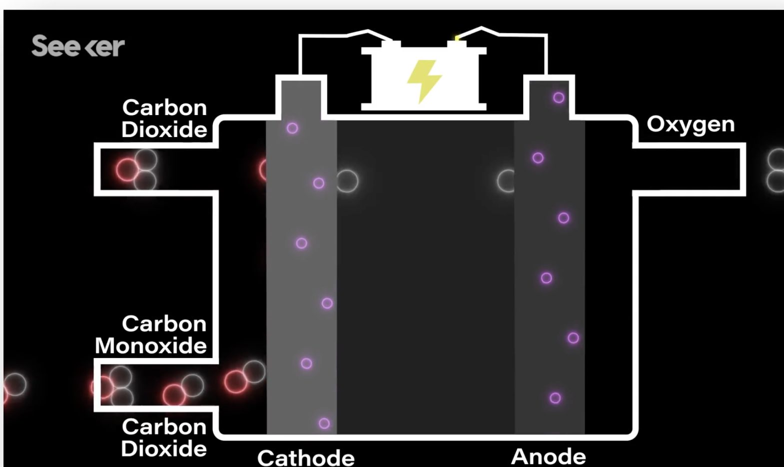
The Advanced Plant Habitat is already being tested on the International Space Station to demonstrate how we can grow wheat in microgravity.[53]

[52] Michael Johnson, "Giving Roots and Shoots Their Space: The Advanced Plant Habitat," Text, NASA, April 11, 2018, http://www.nasa.gov/mission_pages/station/research/Giving_Roots_and_Shoots_Their_Space_APH.
[53] NASA, "Dwarf Wheat Grows in International Space Station's Advanced Plant Habitat," April 11, 2018, https://www.youtube.com/watch?v=ACgTZ01d9O0&t=10s.

Martian Atmosphere

Earth's atmosphere is composed of: 78% nitrogen, 21% oxygen, 1.0% argon, 0.04% carbon dioxide, and small amounts of other gases. Mars' atmosphere on the other hand is 95.32% carbon dioxide, 2.7% nitrogen, 1.6% argon, 0.13% oxygen, with minor amounts of carbon monoxide, water, methane, and other gases, along with a lot of dust.[54]

Using the current technology of solid-oxide electrolysis, with a prototype currently tested onboard the Perseverance rover (which successfully landed on Mars on 18th February 2021), we can take the abundance of CO2 in the Martian atmosphere and use energy to turn it into oxygen. This would allow us to create an air composition that of Earth, sustaining the habitats with fresh air production. [55]



The diagram of the electrolysis process to make oxygen using the Martian atmosphere.[56]

[54] Arizona State University, "Mars Education | Atmosphere"; David R. Williams, "Mars Fact Sheet - NASA," September 27, 2018, https://nssdc.gsfc.nasa.gov/planetary/factsheet/marsfact.html.
[55] M. Hecht et al., "Mars Oxygen ISRU Experiment (MOXIE)," *Space Science Reviews* 217, no. 1 (February 2021): 9, https://doi.org/10.1007/s11214-020-00782-8.
[56] Aboobaker, "NASA's Gold Box Will Make Oxygen on Mars."

You can put electricity into the carbon dioxide bonds, and break it off into carbon monoxide and oxygen molecules. The carbon monoxide would have to be disposed of back into the atmosphere, or used for alternative means.

The output of oxygen would be pumped into various separate oxygen supply and backup tanks, that would keep the molecules sealed and appropriately pressurized. In case of loss or pressure, leak, or loss of a tank, oxygen would always be available in backup tanks. This cuts down reliance on the functioning of one mega oxygen tank, in the ideology of SpaceX's raptor engines. The habitats would be able to switch their oxygen support between various oxygen tanks as need arises, and continue to thrive.

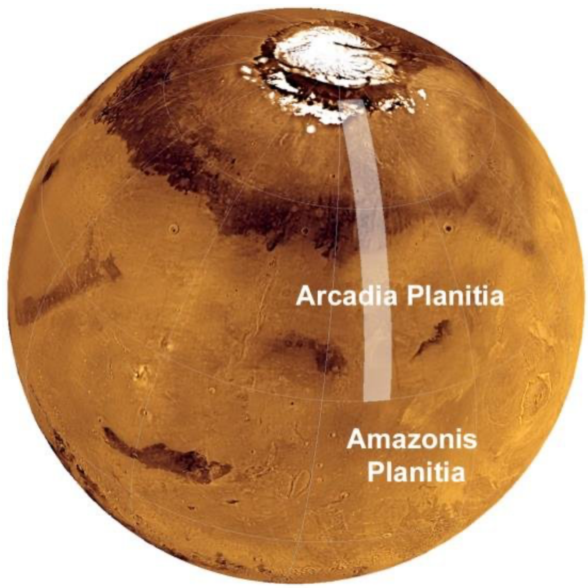
Martian Soil

The study of the Martian soil has provided evidence which shows that it contains all the critical macro- and micronutrients which plants need to grow. Some of these nutrients include: Oxygen, Carbon, Hydrogen, Nitrogen, Potassium, Calcium, Iron, Zinc, Copper, etc. However, soil doesn't always have the right amount of these nutrients, so it depends on where the astronauts would land, but some fertilizer will be needed for the plants to grow successfully. The plants will not be planted outside as the temperature shifts will freeze the plant and kill it. Overall using Martian soil to grow plants on Mars is possible with the help of some man made fertilizer.[57]

[57] Gary Jordan, "Can Plants Grow with Mars Soil?," NASA, October 5, 2015, http://www.nasa.gov/feature/can-plants-grow-with-mars-soil; Roberto Molar Candanosa, "Growing Green on the Red Planet," American Chemistry Society, May 2017, https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/past-issues/2016-2017/april-2017/growing-green-on-the-red-planet.html.

Water Extraction

As our settlement location is on the plains of Arcadia Planitia, we would need to traverse a great distance in order to utilize the frozen CO2 ice caps where water reserves can be found. Whilst we can use transport vehicles for setting water routes in the future, we will need a more convenient method for water extraction that can be utilized in close proximity to our base.[58]



Therefore, we will use a system presented by the Lunar and Planetary Institute, which focuses on extracting water from the soil through heating. By using a focused beam of solar power alternated with energy supply from our nuclear fusion reactors, we can heat up the soil to 200 - 400 degrees Celsius and achieve a successful water extraction by evaporating it from the soil.[59]

[58] Stephen Petranek, Andy Weir, and Jennifer Heldmann, "Extracting Water on Mars | MARS: How to Survive on Mars," National Geographic, October 15, 2016, https://www.youtube.com/watch?v=7M9_p7FooE8.
[59] J. Wiens et al., "Water Extraction from Martian Soil," *Fourth Annual HEDS-UP Forum*, no. 1106 (January 2001): 11–25.

Houses

by Federico Zampedri

Since we are creating a second home on Mars, the most important thing we need is a home. AI Spacefactory has created a concept for a Martian habitat called Marsha. Marsha is made from 3D printed structure with recyclable biopolymer composite.

Building materials:

- a mix of basalt fiber extracted from the Martian rocks
- renewable bioplastics which is synthesized from plants grown on Mars

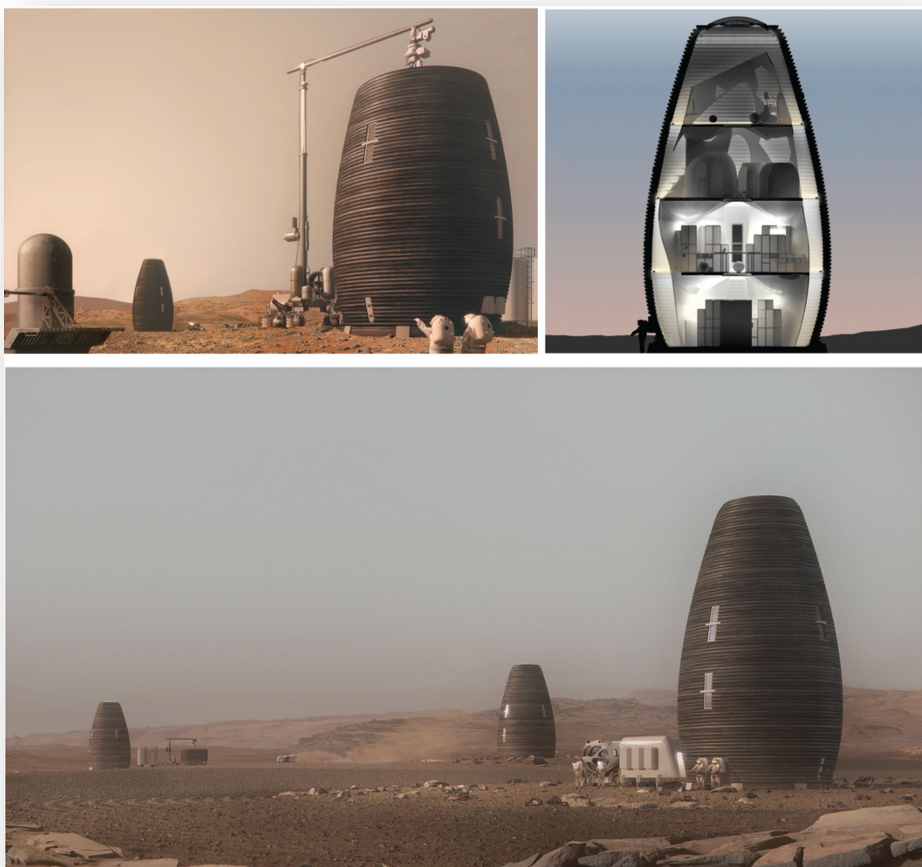
Characteristics of the building materials:

- The polymer composite is recyclable so if a house breaks down, the material can be reused to build another one.
- The polymer composite is 'certified to be two to three times stronger than concrete in compression, our space-grade material is also five times more durable than concrete in freeze-thaw conditions.'[60]
- The bioplastic used to build the structure has a low atomic weight which will shield the inside shell from the cosmic radiation.

Marsha is not like any other habitat concept. It is a multi-floor, egg shaped building. The egg shape structure is designed to handle the high atmospheric pressure and the thermal changes that happen between the night and day. Once the crew arrives on the surface they will temporarily live in the command center. But as soon as the fiber has been extracted from the rocks and the plants have grown to extract the renewable bioplastic, they can start building the houses. We estimate that after 4 months two Marshas will be fully functioning. The Marsha concept right now is made to be somewhat like our control center, but we plan on modifying it and designing it more like a home. All the furniture inside will be 3D printed using plastic containers from food and supplies. These

[60] AI SpaceFactory, "MARSHA by AI SpaceFactory."

two functioning houses will be able to comfortably fit the astronauts. As soon as the production of the two first two Marshas are over, two new Marshas will be built so the astronauts will be able to expand into new spaces and have more personal space for themselves. Our short term goal would be to have a single Marsha for each astronaut so they will each have their own home. Our long term goal will be to create SuperMarshas, which will be combined structures to create even larger spaces for common areas for astronauts to hang out.



'Indirect natural light from the large water-filled skylight and intermittent windows floods the interior while still keeping the crew safe from harmful solar and cosmic radiation. Circadian lighting, designed to recreate Earthly light, is employed to maximize crew health.'[61]

[61] AI SpaceFactory, "MARSHA by AI SpaceFactory."

The Suit

by Federico Zampedri

This is NASA's concept for a Martian space suit which we will use for our manned crew.[62] It has been specifically designed for walking on the Martian surface. It has a salient colored patch in the middle, which helps for the astronauts to recognize each other from distance. Our preparation procedures will ensure that the space suit is made from materials that will protect the astronauts from the radiation as much as it is possible. The suit will also have a universal attachment to the different habitats and the exploration rovers, so the astronauts can move between the habitat and the suit, without bringing in regolith to our settlements.

Tackling Psychological Issues

by Federico Zampedri

Psychological issues are a main concern with deep space travel. The biggest concern that we do not have any data on how we should address is the feelings that the astronauts will feel by being so far away from earth that they will not be able to see it. Being so far away could cause anxiety, sadness, depressive reactions, and even a loss of commitment. Then there is the pressure of being in a toxic environment, that if anything goes wrong with the pressurization, the astronauts

[62] NASA, "Z-2 Spacesuit Prototype," September 30, 2015, https://www.nasa.gov/sites/default/files/thumbnails/image/emu-pxs-z2_0.jpg.

will die. This issue can be tacked by having a safe environment and a well thought out habitat that has safety measures and backups for depressurizations.

Then there are the rest of the psychological issues that can happen with long term mission.

- Social Withdrawal
    - Incorporate Rituals: Weekly bonding activities such as movie nights or just simple talking
- Crew Friction
    - Mostly caused by not having enough personal space, and this is hard to address in the beginning, but in the long term each astronaut will have a personal house (Marsha)
- Boredom and Restlessness
    - Adventurous missions. I would assume that the first astronauts on Mars would have a lot to do to set up a base and then a colony so they will not get bored. But as soon as everything is ready, to prevent boredom and restlessness, events and fun activities would help. Another way to prevent boredom is to stay in contact with family. It will help to send weekly videos to family members and receive a video back, since live communication will not be able to occur.
    - The Crew Would Keep a Personal Astronaut's Journal
    - Changing your environment is one way to interrupt boredom, so stagger all those projects you have hopes of completing, invite variation and change as an alternative to anxious uncertainty
- Decline in Group Compatibility
    - Have a very strong selection of astronauts who all share the mission goal and are motivated to complete the mission
- Lack of Communication
    - Can be helped by problem solving activities where the group comes together and solves a major problem, this will help the crew bond even more.

Then, other ideas to help the astronauts cope with the mission could be: allowing the astronaut some freedom to decide where to build the Marshas, have planned a second mission with another crew to go and replace them, having a house for each astronaut giving them some freedom on how they want to build it, and lastly making sure there is enough natural light going in the over ground habitats which will help with their mental health.

Tackling Physical Issues

by Kara Reiss

Living in space has a huge impact on the human body and in order to travel to Mars, we will need to figure out how to keep our astronauts as physically safe as possible. There are 3 main issues that we need to focus on to create our mission safer for astronauts. These three issues are gravity fields, dangerous closed environments, and the radiation from space.

1. **Gravity:** During the course of the mission, our astronauts will have to go through several different gravity fields. Each change in gravity field will affect each astronaut's spatial orientation, balance, and hand-eye coordination. The gravity fields they endure will also cause astronauts to start losing bone density at a rate of 1% per month. In order to prevent the effects of gravity fields, researchers on the ground will be monitoring the astronauts closely to make sure they are staying healthy. NASA has also found a drug called Bisphosphonates that might help in preventing bone loss.
2. **Closed Environments:** One extremely dangerous factor of space travel is the problem of being in a small closed environment with other people. We have to be very careful, because microbes and immune systems change in space. This can lead to astronauts becoming more susceptible to getting sick. In order to keep the astronauts healthy we will be focusing on monitoring the air quality to make sure that the spacecraft is not contaminated.
3. **Radiation:** The most dangerous aspect of traveling to mars is the harmful rays of space radiation. Space radiation can increase the risk of cancer, cause behavioral changes, and

even damage the nervous system. Considering that Mars receives a lot more radiation than the earth's surface (48x more), we need to make sure we are keeping our astronauts safe with protective shielding. We will need to focus on creating a safe spaceship and living quarters that block as much space radiation as possible. It will be important to address both the daily radiation exposure as well monitoring of and protection from the rare ‘solar flare ups’ which bring massive amounts of radiation.

| The Second Explorers |

Mission Tasks

by Kara Reiss

The second explorers will be tasked with the same goal; colonize Mars and prepare for people to live there. While the first mission might have worked more on temporary facilities, we want the second explorers to think long term. We want them to start building facilities using the SuperMarshas concept which will be safer than the SuperInflatable structure. We also will want them to focus on how they can become self-sustainable on Mars, so we can live there long term. During our second crewed mission to Mars we want to focus on replacing the SuperInflatable structure with SuperMashas. We will combine 4 Marshas together to create bigger facilities that will be able to become common areas, education facilities, and research facilities.

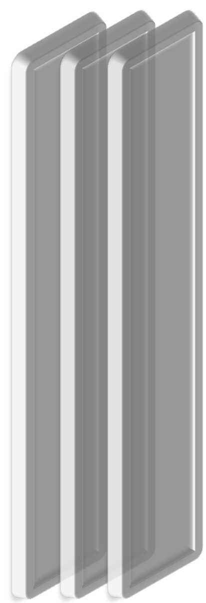
| Phase 2 Recap |

by Federico Zampedri

At the end of **Phase 2** we plan on having built a self-sustaining colony on Mars. The colony would include: a greenhouse able to support about 200 people, build 50 Marsha houses to house the 200 colonists, an oxygen extractor with tanks that is able to supply the oxygen to the Marsha houses and all the other modules, and SuperMarshas to replace the inflatable module and create larger living spaces and maybe even a Martian school. By completing all of these tasks, the astronauts will set up the basis for a long term self-sufficient colony. Once everything is in place and working properly, Mars will be able to welcome about 200 colonists. Once the 200 colonists have settled we can look forward to our future visions.

MARS: A SECOND HOME

Phase 3



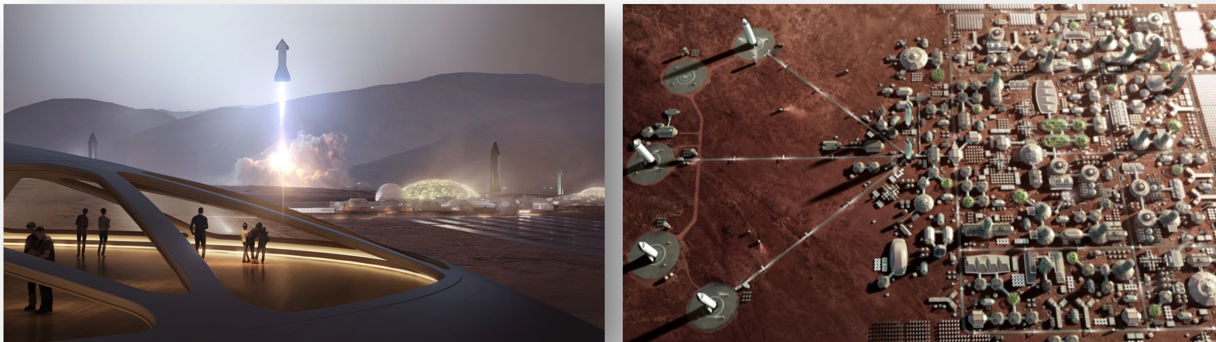
'There is no such thing as science fiction, there is only science eventuality.'

-Steven Spielberg, film director[63]

[63] Steven Spielberg and Malcolm W. Browne, "Visiting 'Jurassic Park' For Real," June 6, 1993, https://www.nytimes.com/1993/06/06/movies/film-visiting-jurassic-park-for-real.html.

| Phase 3 Introduction |

by Tomi Kufel



Each step of the mission, brings us closer to establishing a self-sufficient presence on Mars. By sowing this seed early, with effort and diligent planning, we are putting ourselves in a great position that will allow us to reap the benefits of interplanetary life sooner. [64]

Following the successful set up of our colony awaiting the first 200 settlers, we have visions going beyond the year 2040 that we hope to implement, which make up our **Phase 3**. However, as we are still in progress of developing many of the technologies, and figuring out the reality of some conceptual designs, various aspects in this chapter remain more hypothetical for some years to come. We hope that after the commencement of our space program in 2022, we will be ready to adapt to unforeseen circumstances along the way, and sharpen many different details for this final phase. Adaptation is key to success. As the challenges of reality will test our vision, our team is ready to overcome obstacles and correct our program trajectory with new solutions and inventions.

[64] Elon Musk and SpaceX, "Becoming A Multiplanet Species," https://www.spacex.com/media/making_life_multiplanetary-2017.pdf.

| Future Visions |

The Expansion of Our Colony

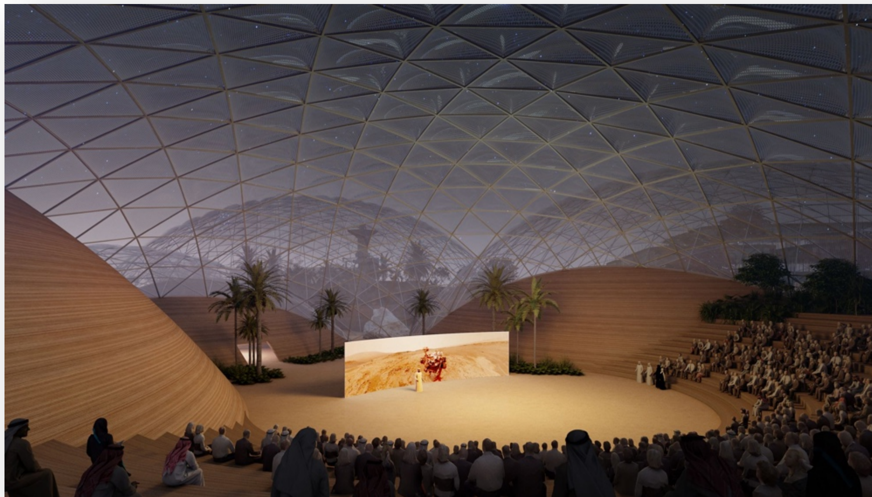
by Tomi Kufel

Following the year 2040, with the growth of the Martian population we hope to proceed with expansion of the physical colony size through the construction of large multi-functional domes. These structures, operating as building-sized microcosms, will host facilities such as science laboratories, educational classrooms, nature resorts, fitness centers with centrifugal work-stations (maintaining the colonists fitness), entertainment lounges, and virtual reality centers (that could not only offer recreation, but provide mission-specific training scenarios). Health centers and hospitals will ensure the safety and wellbeing of our colonists. Science labs as well as schools offering graduate programs will allow new generations of colonists to thrive in a revolutionary academic environment. The opportunities for studying Mars and space, as well as many new inter-connected fields (from mission-oriented engineering and psychological studies to Martian sociology and philosophy), will open doors to discovery and progress. The colonists living on Mars will have the option to return to Earth after the expiration of their contract on Mars (after submitting a request to the interplanetary customs committee), as we hope to maintain a cruise of starships every two years between Mars and Earth. This will allow the colonists to feel free in the solar system, and make the society continuously evolving with the trade of skills and perspectives. Eventually, as is explored later in this chapter, we hope to upgrade the transit system between Earth and Mars to a larger scale with an interplanetary transport cruiser. Throughout this phase we strongly believe that with a united front on Earth, a code of law could be developed for Mars, and politics would be democratically voted upon by all mankind.

Various domes will offer different services and new living spaces besides the traditional SuperMarschas located in the domes. From urban to countryside housing, from Asian to Scandinavian architecture, a wide range of styles will be at our disposal in the fusion of a rich international Martian design.[65]

A set of interconnected domes will provide immense spaces to live in for centuries before terraforming efforts would start becoming viable.[66]

[65] Ville Ericsson, *Mars Colony*, 2017, https://i.imgur.com/1xn8Gi1.jpg.
[66] Bjarke Ingels Group, "Mars Science City," 2020, https://edition.cnn.com/style/article/mars-science-city-design-spc-scn/index.html.



Open meeting spaces could allow for exchange of ideas,
academic presentations, entertainment shows, communal cinema, and speeches.[67]

Over time, with regards to the socio-political matters of our mission, we see it right for Mars to possess its own constitution and judicial system over time. With the government operating in close connection with the United Nations of Earth, we believe that the people of Mars, exposed to their set of challenges and unique environment, will know what is best to lead their people into prosperity and socio-political stability. Nevertheless, Mars and Earth will have to maintain a united front as part of an Inter-planetary United Nations political entity, with the Earth-Mars relationship in part reminiscent to that of the European Union and United States of America.

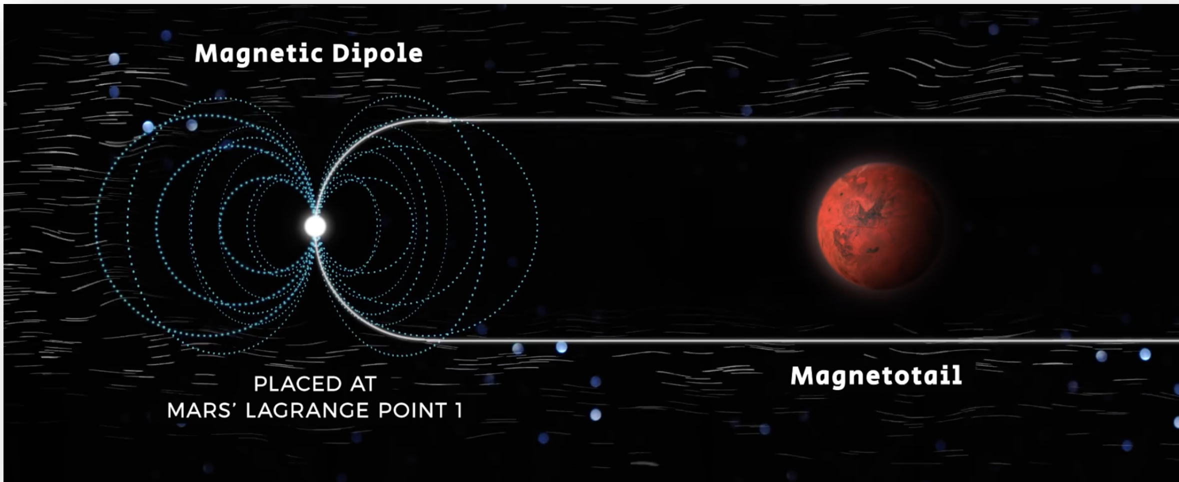
[67] Bjarke Ingels Group.

Magnetospheric Radiation Shielding

by Tomi Kufel

One of the things we hope to address with future technology is radiation threat on Mars that would pose health dangers outside our habitats. Mars' atmosphere is extremely thin as it has been stripped away by solar winds in its history. It has no ozone layer in the atmosphere like Earth does, which means that radiation from the Sun and other astronomical sources reaches the surface unhindered. This radiation is extremely harmful for any exposed organic compounds we know of; the high-speed subatomic particles of cosmic and solar radiation can tear through our bodies and damage our human DNA, increasing risk of cancers and other diseases.

Therefore we believe that one step to protecting our colonies and potentially open a whole door for the terraforming of Mars, is the creation of an artificial magnetosphere. Some speculate that an armada of mirrors to reflect solar radiation could help solve the issue, however, we believe that a more effective solution may arise by the end of the 21st century. Researchers at NASA propose the creation of a small artificial magnetosphere, that would repel solar winds, and create a shadow tail of decreased radiation in which Mars would be shielded (an area called the magnetotail). Initially, the radiation shielding could cover an area of Mars around our colony, and with expansion of this system, encompass the whole planet in the magnetotail.



According to J.L. Green et al. "an artificial magnetosphere of sufficient size generated at L1 allows Mars to be well protected by the magnetotail."[68]

As seen in the illustration above, this would require the placement of a satellite at Mars's first lagrange point (L1). This is a point in space between the Sun and Mars, in which the gravity of the two is in equilibrium on the object, and which can float in orbit around the Sun, whilst still remaining its relative position to the two objects.

Instead of creating a megastructure in space with thousands of different pieces in the form of a super-mirror, it may be more viable to construct a high energy magnetic field generator, placed in orbit at L1 between Mars and Sun. The magnetotail would then create a radiation-free shadow zone. Many questions behind this theoretical proposal keep the technology out of reach at the present moment, as it remains for the scientists to research a viable energy source to supply such strong and stable magnetic dipole. Whether the answer is laser beamed solar energy, nuclear fusion

[68] J. L. Green et al., "A Future Mars Environment For Science and Exploration - Planetary Science Vision 2050," 2017, https://www.hou.usra.edu/meetings/V2050/pdf/8250.pdf.

technologies, or a different solution entirely, it would need to robustly generate enough teslas to make this concept feasible.

The idea for the magnetic dipole has already been proposed as the Planetary Science Vision 2050 Workshop. Scientists believe that besides using this technology to shield our colony from radiation, the magnetic deflection of solar wind could also mean a faster restoration of the Martian atmosphere.

Private Martian Industries

by Tomi Kufel

In the final phase of the program, a gateway for private industries to come to Mars has to be opened in order to create a free market which will help us acquire Martian resources, and offer daily services to our colony - from entertainment and recreation (ex. Martian Google and Netflix), to foods (ex. Martian Nestle) and technologies (ex. Martian Apple). We also believe that many new start-ups and technological breakthroughs will be made on Mars, as it will be the very epicenter of mankind's skilled demographic.

Starlink 2

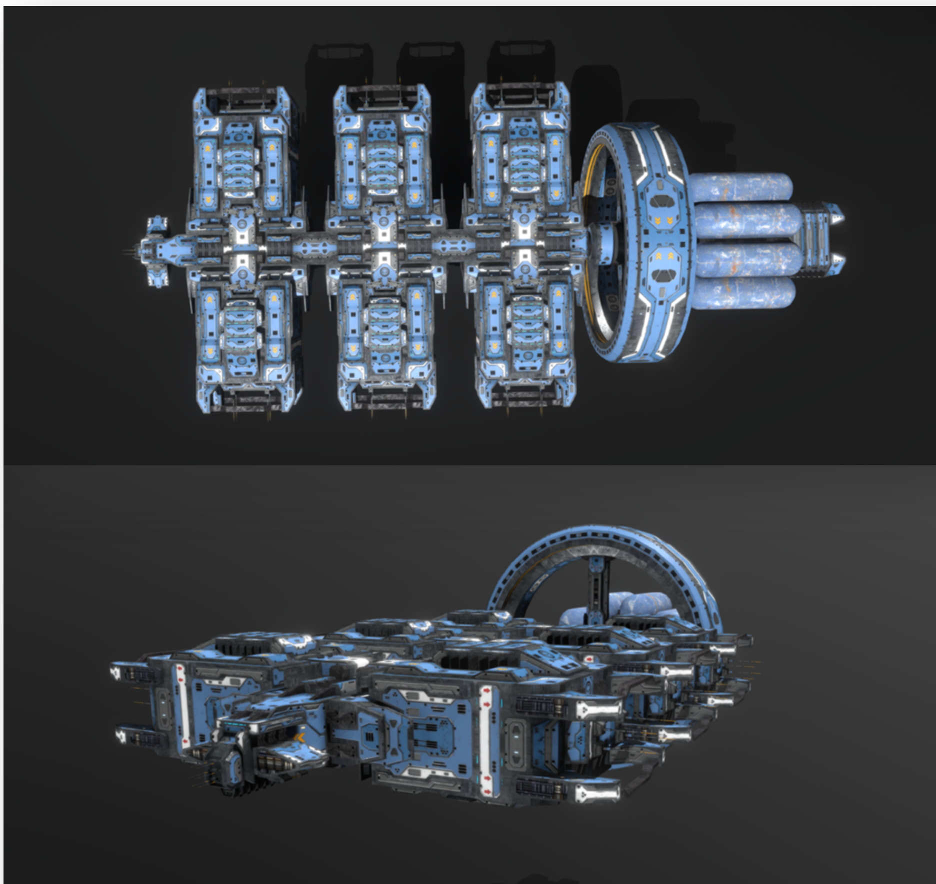
by Tomi Kufel

After completion of SpaceX's Starlink on Earth, we hope to begin work on developing a reliable bandwidth connection from orbit around Mars. Whilst fiber optic networks will work for joining together the structures of a single city, Starlink 2 will enable great services to new outpost outside of Arcadia Planitia. This would also aid communication on exploration trips to uncharted territories. These satellites could be constructed on the Martian surface, and launched with locally sourced fuel. It would be a hallmark of our achievement in demonstrating the success and self-reliance of Mars.

Future Interplanetary Transport Cruiser and New Launch Points

by Mason Friesch

In the future, our plan is to use Mars as a launchpad to go deeper into our solar system and beyond. The plan for an interplanetary transport cruiser is extremely conceptual as there is not a lot of research on how we can achieve this, but this is an important aspect of making sure Earth and Mars are well-connected in Phase 3.



A hypothetical design of a transport craft t that could be constructed with Lunar resources, and launched from low-gravity Moon on a trip to Mars. A larger space cruiser could transport more people and cargo than previous starship designs.[69]

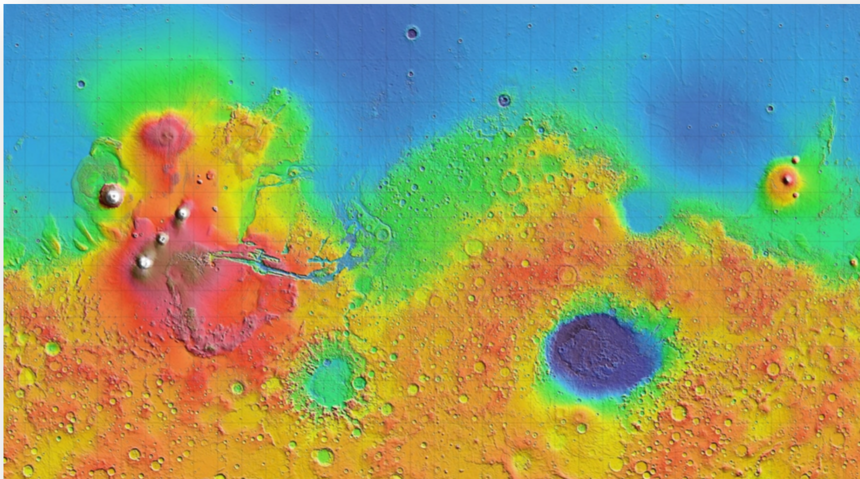
[69] Markus Schüler, "Colony Ship Concept - 3D Model by MSGDI," February 3, 2018, https://sketchfab.com/3d-models/scifi-colony-ship-ab1ffedad66c4ce8bc9a1b89e5b78dfd.

Once we establish our own self-sustaining colony on Mars with enough colonists there to make it fully functioning, we can build a launchpad to send spacecrafts farther into space. Right now, we can only launch rockets from Earth, which provides a set of constraints due to Earth's gravity and its location in the system. If we construct launch points on Mars, we will expand the range of our possibilities. This will be invaluable in assisting with our ultimate efforts to search for life in our solar system and beyond, as well as help with harvesting materials and resources from other celestial bodies. After Mars, looking to set outposts on its natural satellites, Phobos and Deimos, could improve our transportation systems and in-situ resource utilization. Instead of shipping resources from the Earth's moon, Phobos and Deimos could be used as hotspots for supporting construction efforts back on Mars, with the launch of bigger spacecraft to trade resources back with Earth.

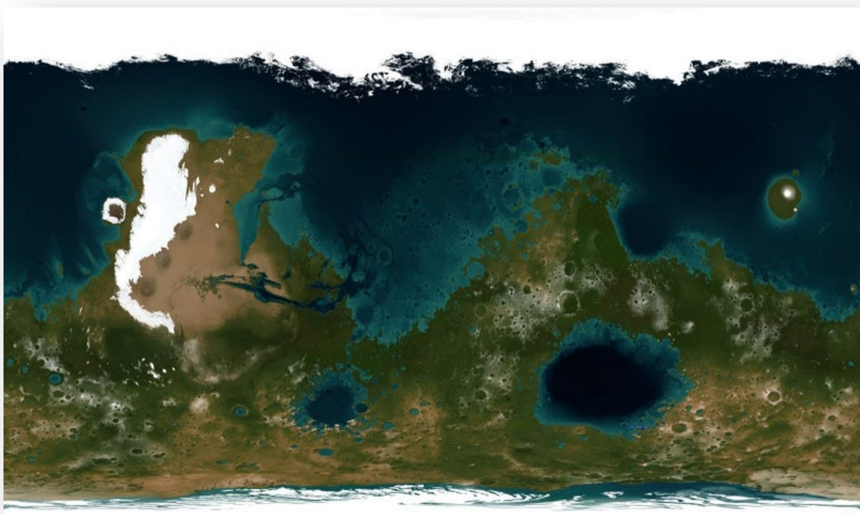
| Phase 3 Recap |

by Tomi Kufel

We hope to conclude **Phase 3** with a booming Martian economy, a thriving city of Marschas and interconnected dome structures housing over 100 000 inhabitants, and rich trade with Earth, all by the end of 2200. With progress, a hypothetical next phase of our Mars Colony would come to witness the crystallization of solid methods for terraforming. Melting of the ice caps and transformation of the Martian atmosphere may become viable by this time. By the end of Phase 3 and our space program, we will have successfully established a checkpoint for going further beyond to the outer planets of our solar system, and help us to, one distant day, become an interstellar species.



A shaded relief map of Mars created with data from the Mars Global Surveyor's laser altimeter (MOLA) collected between 1997 and 2001, based on a total of approximately 671,121,600 laser pulses.[70]



Based on the data from MOLA, this is an artist's renditioning of how Mars could hypothetically appear from satellites after terraforming operations following the completion of our space program..[71]

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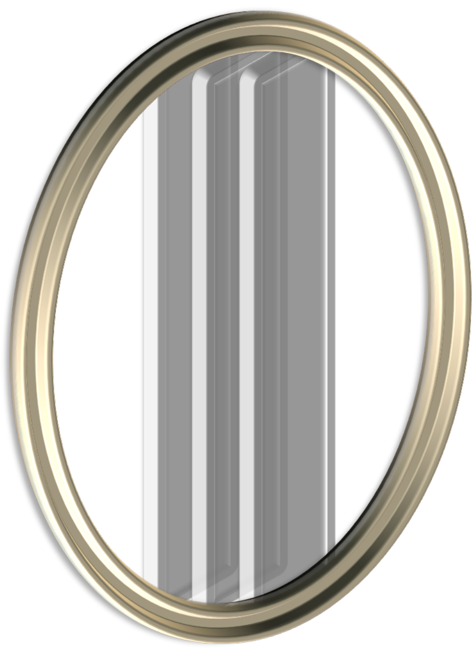
[70] David E. Smith et al., "Mars Orbiter Laser Altimeter: Experiment Summary after the First Year of Global Mapping of Mars," *Journal of Geophysical Research: Planets* 106, no. E10 (October 25, 2001): 23689–722, https://doi.org/10.1029/2000JE001364; USGS Astrogeology Science Center, NASA, and PDS, "Mars MGS MOLA Global Color Shaded Relief 463m V1," 2010, https://astrogeology.usgs.gov/search/map/Mars/GlobalSurveyor/MOLA/Mars_MGS_MOLA_ClrShade_merge_global_463m.

[71] n/a, *Hypothetical Map of a Terraformed Mars [1024 x 512]*, 2013, https://external-preview.redd.it/M0WMPksF5_x1Oseyaq-CSD3V6jmX2yY_PITCoZH7uVI.jpg?auto=webp&s=c6dc55b6f1a483f3bb16850e5a9089e5f0fc0b5e.

Program Support and Funding

by Federico Zampedri



*'I don't think the human race will survive the next thousand years, unless we spread into space. There are too many accidents that can befall life on a single planet.
But I'm an optimist. We will reach out to the stars.'
— Stephen Hawking, theoretical physicist and cosmologist*[72]

[72] Roger Highfield and Stephen Hawking, "Colonies in Space May Be Only Hope, Says Hawking," October 16, 2001, https://www.telegraph.co.uk/news/uknews/1359562/Colonies-in-space-may-be-only-hope-says-Hawking.html.

| Public Support |

The Media

The main way to gain public support in the 21st century is to use The Media. Our main goal is to use the media to keep our audience engaged in the process and up to date on what is going on throughout the entire process. If the audience is engaged and feel like they are part of the project, they will want to see the project come to life and become a reality.

Advertising Campaigns

Start advertising campaigns for the mission to bring the knowledge to the public. Inspire people that we can be living on Mars soon. If the public feels engaged with the mission and knows about the final goal they will be more willing to support the mission.With more public support, the Government and NASA would be willing to create more and increase the budgets for the mission to Mars.

Weekly/Monthly Updates

Create short weekly or monthly documentaries to show the public what is being created and at what stage the mission is. Provide new discoveries to the public and make it accessible for people to track the process of the overall mission.

Streamed Reality TV

Create a reality TV that is streamed on a streaming service where people can follow the progress of the mission, but to mainly make the audience feel part of the mission. The reality TV show can explain the decision making process and reveal new discoveries. It can show how the rockets are being built, what the crew capsule will look like and everything else related to the mission.

Website about the Mission

Made accessible with easy to understand explanations about how the mission is going to play out. Provide new discoveries and images from the rovers, supply mission, and the building progress of habitats. Advertise educational programs on websites.

Public Inputs

Create surveys with different options for the mission and allow the public to make decisions. This will make the followers of the mission feel even more engaged and part of the mission which will massively increase public support. An option could be the 3D printed furniture placed in the Command Center.

Space Tourism

We plan on using space tourism to gain mostly public support but also open up new opportunities for funding. Whilst civilians will not be able to directly participate in space tourism during the first two phases of our mission, it is in our vision to open up our facilities to visitors, and use our idle starship to transport people to our outpost on the Moon and Mars. We plan on cooperating with Space Adventure, a private space tourism company. To date they have arranged 8 spaceflights for 7 clients, who cumulative spent 80 days in space and travelled 30 million miles in space. They have recently teamed up with SpaceX to send space tourists into space with the Dragon Capsule. The plan is to be able to send passengers on an orbital trip that would last about 5 days. These missions could start as early as 2021.[73] This could be an opportunity to send potential investors on a trip around the earth to have them feel what space is like and get them excited about funding our mission. Space adventure could also be a potential partner to allow space tourism to our outpost on the Moon and later to the one on Mars. Once the self-sustaining colony is set up we could use the Space Adventure program to send space tourists to our Marian outpost.

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[73] Tariq Malik, "SpaceX Will Fly Space Tourists on Crew Dragon for Space Adventures," February 18, 2020, https://www.space.com/spacex-crew-dragon-will-fly-space-tourists.html.

| Funding |

Government Funding

Funding is always the biggest problem with space exploration missions. The government will not fund anything that does not have public support. So once public support is established, funding from the government will not be impossible to get. Second, no private company will provide funding if there is no return on investment, that is when space tourism comes into place. Lastly, since this mission will definitely not be cheap, cooperation between space agencies and private space companies around the world will be crucial to making this mission happen.

- NASA's budget will be our first go to. In the next few years the budget that they will have from the U.S. government will be:[74]
    - 2020: $22 599 billion
    - 2021: $25 246 billion
    - 2022: $27 159.6 billion

These numbers might seem big and able to fund the mission, but not all that money will go to the mission. NASA has other programs that they need to fund and so a fraction of those numbers will go to space exploration

- NASA's Space Exploration Estimated Budgets[75]
    - 2020: $6 017.5 million
    - 2021: $8 761.7 million
    - 2022: $10 299.7 million

[74] NASA, "Fiscal Year 2021 Budget Estimates," March 13, 2020, https://www.nasa.gov/sites/default/files/atoms/files/fy_2021_budget_book_508.pdf.
[75] NASA, "FY 2021 President's Budget Request Summary," 2020, https://www.nasa.gov/sites/default/files/atoms/files/fy2021_congressional_justification.pdf.

The Space Exploration Estimated Budgets compared to NASA's overall budget are significantly smaller. Some of these are also estimates of what NASA is looking to get and it has not yet been approved by the government. Other sections of the budgets can be included too but just a fraction of that fraction of the budget will be allocated to research on the mission to Mars. Since we would be cooperating with other space agencies around the world, examples of what their budget looked like over the past few years will give us an understanding of how much they can contribute.

- JAXA Budget (Even though the numbers are from the past years we can get an idea of what the budget is)[76]
    - 2016: ¥181 billion (approx.. $1.65 billion in April, 2021)
    - 2017: ¥182.7 billion (approx. $1.67 billion in April, 2021)
    - 2018: ¥154 billion (approx. $1.40 billion in April, 2021)
- ESA Budget
    - 2019: €5.72 billion (approx. $6.81 billion in April, 2021)[77]
    - 2020: €6.68 billion (approx. $7.24 billion in April, 2021)[78]

Similarly to NASA, these two space agencies have other missions and programs to fund such as the International Space Station. Therefore, only a portion of their budgets will be allocated to the mission to Mars.

[76] JAXA, "Transition of Budget," 2019, https://global.jaxa.jp/about/transition/index.html.
[77] European Space Agency, "ESA Activities and Programmes," January 14, 2019, https://www.esa.int/ESA_Multimedia/Images/2019/01/ESA_Budget_2019.
[78] ESA, *Budget 2020: ESA Activities and Programmes*, 2020, https://www.esa.int/ESA_Multimedia/Images/2020/01/ESA_budget_2020.

Private Funding

Funding for space mission exploration is always very hard to acquire. We are welcoming private investors for the development of our mission. Private investors can bring new technology and developments to the mission, as well as support a cause for humanity with their input. By investing in our mission, their return will be a priority in either travelling to Mars, or bringing their own technology and developments to make Mars a more suitable space for humans to live.

| Cooperation and Private Investors|

Cooperation is crucial to make this mission happen, therefore we made a list of potential companies that could partner up with us to develop different sections of the mission.

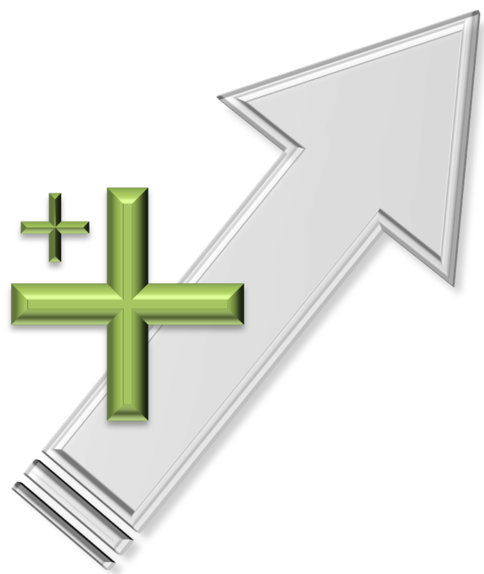
- SpaceX
  - Since we are using a version of the Starship Rocket as the launch vehicle and transit vehicle we would partner up with SpaceX and assign those tasks to them.
- Hassell
  - The architecture firm will provide the structural plans and the modular robots for the creation of the 3D printed cave structure where the command center will be built.
- AI Spacefactory
  - After our first explorers are on Mars, they will start building the Marshas. AI Spacefactory will put together the plans for those structures and provide the 3D printers needed to 3D print the Marshas, and later, the SuperMarshas.

- JAXA+Toyota
    - JAXA could keep the partnership with Toyota and develop a Mars rover similar to the Lunar rover. They could design the rover with the specific features needed for the Mars terrain and the universal latch that will be able to attach to the habitats
- Lockheed Martin
    - Lockheed Martin will build our satellite system. Their 3.0 GPS "Vespucci" will provide the accuracy needed for our mission
- NASA+ESA+ROSCOSMOS
    - They would provide the crew of astronauts and supervise the mission. By giving a share to every space agency they would be able to combine budgets.

MARS: A SECOND HOME

Mission Benefits

by Tomi Kufel and Mason Friesch



'In the long run, every planetary society will be endangered by impacts from space, every surviving civilization is obliged to become spacefaring, not because of exploratory or romantic zeal, but for the most practical reason imaginable: staying alive.'
— Carl Sagan, astronomer and astrophysicist[79]

[79] Carl Sagan and Ann Druyan, *Pale Blue Dot* (Random House Publishing Group, 2011), 306, http://api.overdrive.com/v1/collections/v1L2BMAAAAM0GAAA19/products/4410f8f2-1e66-42f1-ac5e-ded30071317a.

Our space program, MARS: A SECOND HOME, brings a wealth of opportunities and advantages for us to embrace as a human species. Traveling to space not only benefits our governmental and private agencies like NASA, ESA, JAXA, SPACEX, but our entire international community as a whole. As a species, we will enter an age of new discovery about ourselves and the universe around us, as well as expand the boundaries of what has ever been done. We strongly believe in five principal elements that accompany our efforts, which stand as the ultimate pillars of our space program.

1) Discovery of New Life

The search for life on Mars will begin under the surface where liquid water was once found. We will also look for certain energy hotspots like geothermal locations which can provide a place for life. Finding life will be the biggest benefit. As well as looking for life itself, we will also look for signs of life like where carbon is present and even fossils in the sedimentary rock. Finding any sorts of life or remnants of life would drastically change our understanding of the universe. It would show humans that they are not unique on Earth and that there are other places throughout the universe that are harboring life just like Earth. This would also help on the funding and public support side of our mission. If there is life on Mars, people on Earth will be very excited to explore even more celestial bodies for life. The space industry will have immense support from the public for years to come.

2) Valuable Natural Resources and Development of New Technologies

One of the biggest benefits of going to Mars is the return on our investment. The mission to Mars is going to be one of the most expensive things the world has done. One of the most underestimated potential of becoming multi-planetary and setting out to explore space are all the technological breakthroughs, human ingenuity and resource trade that Earth will benefit from. We can look to our history for evidence of how space programs can be incredibly fruitful endeavors. According to President George Bush, the Apollo Program of the 1960s had "the best return on investment since Leonardo da Vinci bought himself a sketchpad".[80]

3) Survival of Mankind

Possibly the foremost significant reason we need to consider when it comes to the benefit of becoming a multi-planetary species is human survival. There is no point trying to make a hard drive back up after it is already corrupted, and also blown into smithereens. We need to open our consciousness to realize how pressing certain issues are, even if they are not affecting us directly at the pressing moment. Going multiplanetary is like a very good insurance investment. There are a number of catastrophic events threatening human existence here on Earth. These events range from biological (pandemics), social (nuclear and biological warfare leading to a mutually assured destruction), climatic (collapse of our environment) and extra-planetary (asteroid impacts). We need to prepare ourselves for the unpredictable. Why are we alone in the universe? Maybe all the living species that lived before us since the big bang billions of years ago, always met their fatal end because they lost the race against the clock to become multi-planetary? Setting up human outposts on other planets as early as possible in our race will mean a significantly higher chance of long-term survival.

4) Steppingstone for Exploring The Universe

In the future, our plan is to use Mars as a launchpad to go deeper into our galaxy and beyond. This is extremely conceptual and there is not a lot of research on how we can achieve this, but this is our vision. Once we establish our own self-sustaining colony on Mars with

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[80] David L. Chandler, "Taking the Next Step: Analysts Weary of President's Go-It-Alone Space Push," *Boston Globe*, July 31, 1989, 21.

enough colonists there to make it fully functioning, we can build a launchpad to send probes farther into space. Right now, we can only launch our deep space probes from Earth, which gives the probes limited range. However, if we were to launch from Mars which lies at the outskirts of the inner region we would have a significantly larger range to send satellites to. This could prove invaluable because this may help us search for life in the solar system. We could then potentially begin to send manned missions to other stars or even asteroids. This ability to launch off Mars could also help with harvesting the materials and resources from asteroids in the asteroid belt which encircles the inner planet region of our system.

5) Uniting The World

Besides the economic return, we can also hope to see global political advantages to pursuing a mutual ultimate goal of becoming a space faring civilization. Whilst there may be risks of conflict in the race to conquer the final frontier, becoming a multi-planetary species will require the collaboration of all Earth. Mars will not be reserved for just Americans, Venus for Russians, and Pluto for the Japanese. The endeavor of going to space will mean uniting all of us as one, and seeing beyond our differences and nationalities. Shared goals will strengthen political ties internationally. The core values and philosophy of our multiplanetary missions will lead to the union of all mankind as a single race more than ever before.

Research Reflection

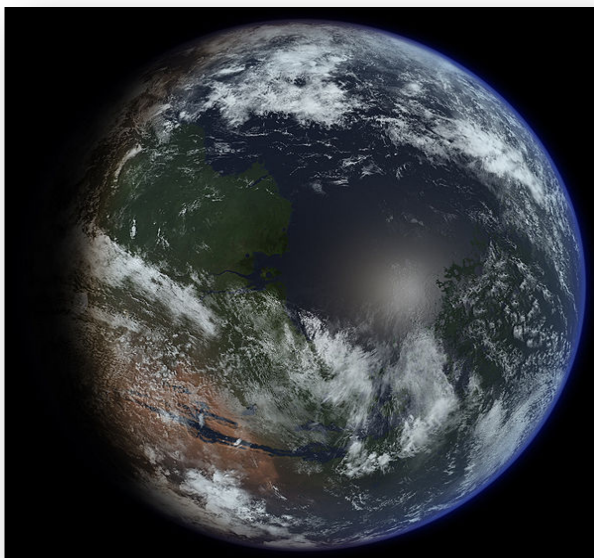
by Tomi Kufel, Federico Zampedri, Kara Reiss and Mason Friesch

Future continuation of this research could deepen the detail of each phase and provide greater analysis of each mission aspect. Further evaluation over the technologies (both real and conceptual) that we have decided to incorporate, could be examined alongside other alternative solutions and new innovations that may rise in the coming months and years. The landscape of space research and space technologies has been steadily evolving in the past few years with the resurgence of interest in Mars. Therefore, as new technologies reveal themselves on the horizon, they should be critically considered for their candidacy in strengthening our space program. Nonetheless, our research still goes to show just how many elements one needs to consider when embarking on a manned mission to space – especially when it is a multi-decade effort to colonize another celestial body. Whilst many aspects of the space program remain to be researched and studied by the engineers and designers in the field, our findings from a wide range of secondary sources come to show very promising results. All the way from surface composition of the Lunar surface and testing of new Starship designs by SpaceX for manned crew, to systems in which we could extract oxygen from Marian atmosphere and water from Martian soil – we are closer than ever to bringing people to Mars.

Conclusion

by Tomi Kufel, Federico Zampedri, Kara Reiss and Mason Friesch

The following space program which lies ahead of us is one of the most ambitious endeavors ever undertaken by our species. All the phases culminate together to provide a holistic blueprint of what would be necessary to prepare for, send and settle on Mars, starting this decade and continuing onwards to the 22nd Century.



There will come a day that a Martian will look back on history books,

and be taken by surprise to see his home called Red Planet.[81]

Our program proposal will set our international community on a grand space adventure that will be filled with historic milestones for humanity. There will be times of great triumphs and inspiration, as well as times of hardship and endurance. As we will overcome an array of immense challenges never before faced, our collaboration and ingenuity will carry us onwards. What we plan to achieve with colonizing Mars will be a feat that will re-define what it means to

[81] Ittiz, *Terraformed Mars*, 2009, https://upload.wikimedia.org/wikipedia/commons/7/78/TerraformedMars.jpg.

be human. We have the potential within each one of us to unite our efforts as a single global society, overcome any adversity on the path to the stars, and pursue all that may have at first seemed impossible.

With MARS: A SECOND HOME, we have the very blueprint for ensuring our species flourishes. As we enter the third millennia of our age, our group strongly feels tat this may be the very project that will ensure life itself survives and prospers in our universe for the next centuries to come. We are at a key moment in history, in which our dreams and visions are starting to converge with our skillset and technology, helping us turn futures into reality. We stand in a position that is enabling us to pursue that what many have only longed to experience.

Now is the time to take action and set out on the space odyssey. This is how we will become, *a multiplanetary species*.

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