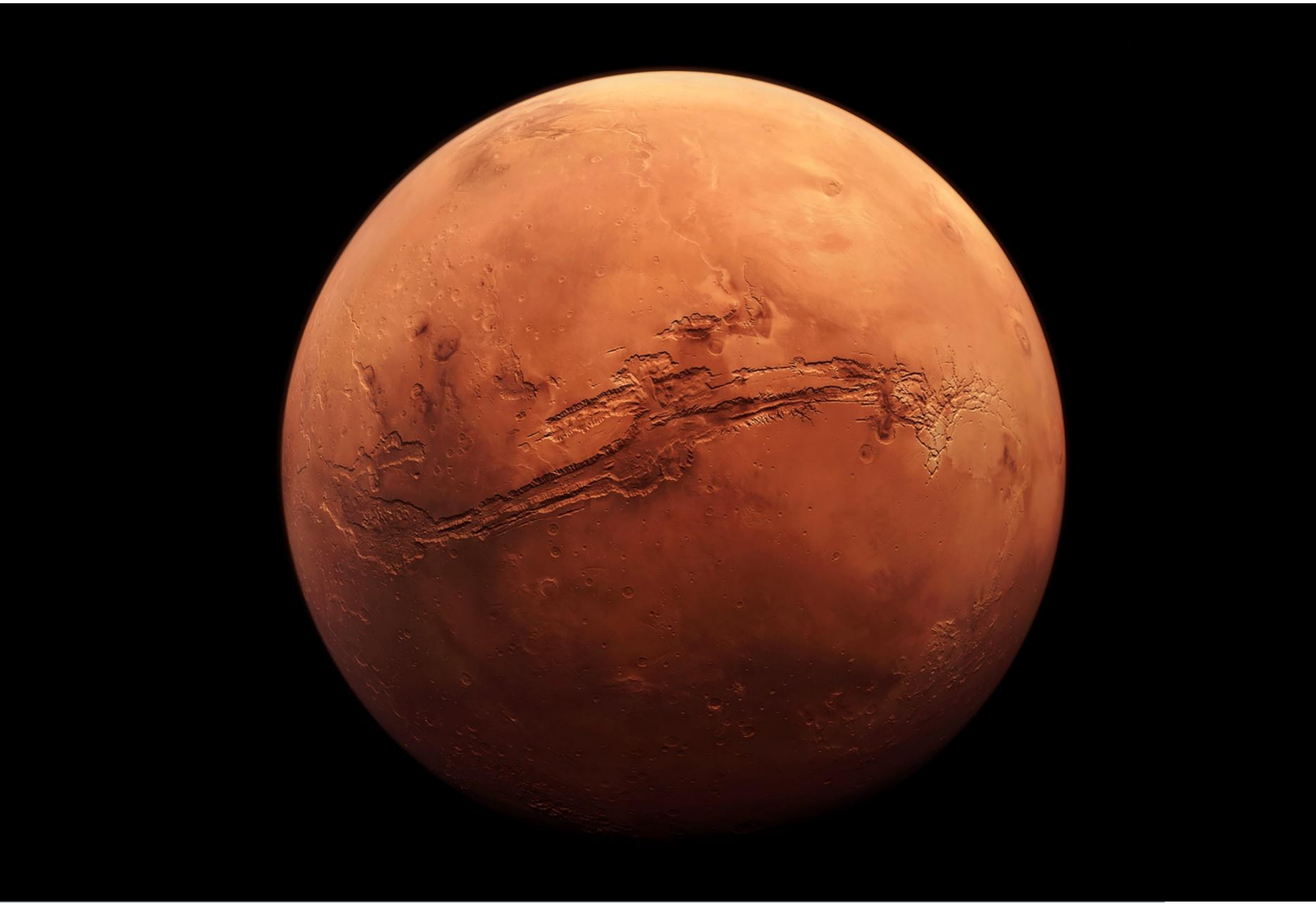
CALL

for

Architects

to design human habitat on Mars

(Note: Civil engineers may also participate, as well as **students** of Architecture and Civil engineering)



Colonization of Mars

Dear Architect (Space Architect),

Committee for Space Programme Development (КРСП/CSPD) *in cooperation with organizations, institutions, agencies and companies from over 60 countries invites you to, this time, direct your knowledge, vision and ideas towards a contribution to humanity.*

As you read the terms of reference, you will understand why it is necessary to involve as many people as possible in such projects. The more people think about this topic, the better for humanity, ideas and solutions will come by themselves, and the more ideas and solutions there are, the more humanity will benefit. During this process, the change of awareness in terms of living on Earth will be a side effect in the most positive and broadest possible sense. Earthlings will begin to appreciate more what they have, where they live and to behave more responsibly because they will have something to compare their habitats with, i.e. the benefits of living on Earth and, in this case, on Mars. By reading the document you will understand that this is not a classic call for choosing the best solutions because the project is much broader, the goals are much broader, participants must first learn a lot about Mars, then compare it to the conditions on Earth and then apply acquired knowledge in ideas to design human habitat on Mars. During this process a change of awareness is inevitable because you will start to think differently. There are many examples that when looking for solutions to more complex environments, more complex conditions, more complex problems, it is very easy to find solutions to problems that are less demanding in environments and conditions that we only thought were complex, i.e. there is an overcoming of the established way of thinking and approaching to solving problems. There are many examples that engineers looking for solutions for Space applications, actually invented technologies that are now in use on Earth. That is one of the goals of this project as well.

The main idea is for experts from Serbia to join the program important for humanity, i.e. to enable small countries to be side by side with "big players", because the basic rule in Space engineering and everything related to Space is that everyone is equally important and that everyone can contribute in its own way. Serbia is a country of extremely talented people, but it needs motivation, it needs stimulus and an opportunity to show that talent. So far, this has been done several times in this area, although Serbia is very small and has been late in Space engineering for more than 60 years: UNITY program (3 Satellites launched), Water Quality Management via Satellites and Early Warning System, World CanSat/Rocketry Championship, Planetary Ground Stations (Antennas) Network etc., are some concrete examples, results and indicators that we really can do it. Space engineering is interdisciplinary, which means that there is room for everyone. In this case, for you: Architects and Civil engineers.

Reasons for colonizing Mars include curiosity, the potential for humans to provide more in-depth observational research than unmanned rovers, economic interest in its resources, and the possibility that the settlement of other planets could decrease the likelihood of human extinction. Mars habitats must contend with surface conditions that include almost no oxygen in the air, extreme cold, low pressure, and high radiation. Alternatively, the habitat may be placed underground, which helps solve some problems but creates new difficulties.

One challenge is the extreme cost of building materials for Mars, which by the 2010s was estimated be about US$2 million per "brick" to the surface of Mars. While the gravity on Mars is lower than that on Earth, there is increased solar radiation, temperature cycles, and the high internal forces needed for pressurized habitats to contain air.

To contend with these constraints, Architects have worked to understand the right balance between in-situ materials and construction, and ex-situ to Mars. For example, one idea is to use the locally available ***regolith*** *to shield against radiation exposure, and another idea is to use transparent ice to allow non-harmful light to enter the habitat. Mars habitat design can also involve the study of local conditions, including pressures, temperatures, and local materials, especially water.*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Mars mission concepts and timelines

Since the 20th century, there have been several proposed human missions to Mars both by government agencies and private companies.

Most of the human mission concepts as currently conceived by national governmental Space programs would not be direct precursors to colonization. Programs such as those being tentatively planned by NASA, Roscosmos, and ESA are intended solely as exploration missions, with the establishment of a permanent base possible but not yet the main goal.

Colonization requires the establishment of permanent habitats that have the potential for self-expansion and self-sustenance. Two early proposals for building habitats on Mars are the Mars Direct and the Semi-Direct concepts, advocated by Robert Zubrin, an advocate of the colonization of Mars.

At the February 2017 World Government Summit, the United Arab Emirates announced a plan to establish a settlement on Mars by 2117, led by the Mohammed bin Rashid Space Centre.

SpaceX has proposed the development of Mars transportation infrastructure in order to facilitate the eventual colonization of Mars. The mission architecture includes fully reusable launch vehicles, human-rated spacecraft, on-orbit propellant tankers, rapid-turnaround launch/landing mounts, and local production of rocket fuel on Mars via in situ resource utilization (ISRU). SpaceX's aspirational goal as of 2017 was to land their cargo Starships on Mars by 2024 and the first 2 crewed starships by 2026.

Overview

Significant challenges for Mars habitats are maintaining an artificial environment and shielding from intense solar radiation. Humans require a pressurized environment at all times and protection from the toxic Martian atmosphere. Connecting habitats is useful, as moving between separate structures requires a pressure suit or perhaps a Mars rover. One of the largest issues lies in simply getting to Mars, which means “escaping” Earth's atmosphere, sustaining the journey to Mars, and finally landing on the surface of Mars. One helpful aspect is the Mars atmosphere, which allows for aerobraking, meaning less need for using propellant to slow a craft for safe landing. However, the amount of energy required to transfer material to the surface of Mars is an additional task beyond simply getting into orbit. During the late 1960’s, the United States produced the Saturn V rocket, which was capable of launching enough mass into orbit required for a single-launch trip holding a crew of three to the surface of the Moon and back again. This feat required a number of specially designed pieces of hardware and the development of a technique known as the Lunar Orbit Rendezvous. The Lunar Orbit Rendezvous was a plan to coordinate the descent and ascent vehicles for a rendezvous in Lunar orbit. Referring to Mars, a similar technique would require a Mars Excursion Module, which combines a crewed descent-ascent vehicle and short stay surface habitat. Later plans have separated the descent-ascent vehicle and surface habitat, which further developed into separate descent, surface stay, and ascent vehicles using a new design architecture. In 2010 the Space Launch System, or growth variants therefore, is envisioned as having the payload capacity and qualities needed for human Mars missions, utilizing the Orion capsule.

One of the challenges for Mars habitats is maintaining the climate, especially the right temperature in the right places. Electronic devices and lights generate heat that rises in the air, even as there are extreme temperature fluctuations outside.

One idea for a Mars habitat is to use a Martian cave or lava tube, and an inflatable air-lock was proposed by Caves of Mars Project for making use of such a structure. The idea of living in lava tubes has been suggested for their potential to provide increased protection from radiation, temperature fluctuation, Martian sunlight, etc. An advantage of living underground is that it avoids the need to create a radiation shield above ground. Another idea is to use robots to construct the base in advance of human's arrival.

The use of living plants or other living biologicals to aid in the air and food supply if desired can have major impact on the design. An example of how engineering demands and operational goals can interact, is a reduced-pressure greenhouse area. This would reduce the structural demands of maintaining air pressure, but require the relevant plants to survive at that lower pressure.

Taken to an extreme, the question remains just how a low a pressure could a plant survive in and still be useful.

A Mars habitat may need to focus on keeping a certain type of plant alive, for example, as part of supporting its inhabitants.

NASA's Caves of Mars study suggested the following food and food production characteristics:

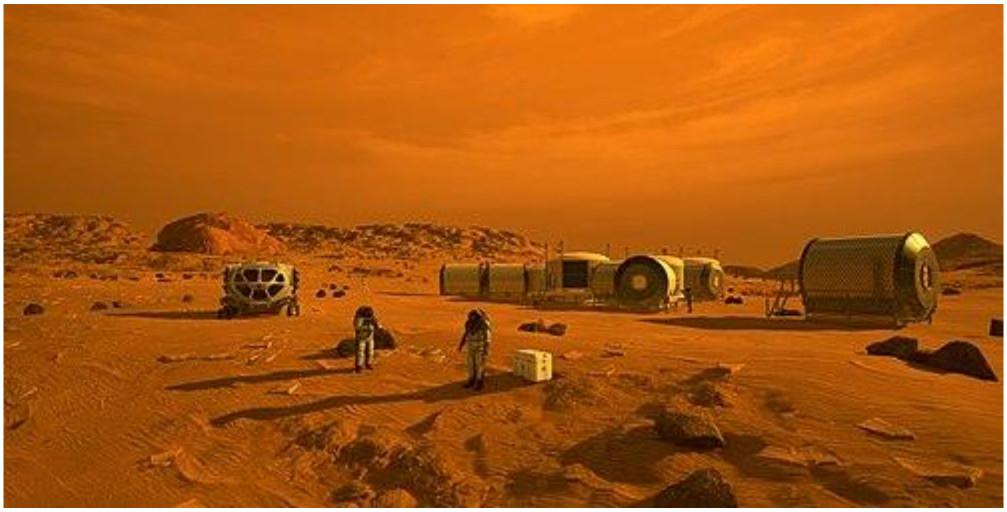
- Rapid growth
- survival in low light
- wide pH range
- high nutrition
- minimal waste

The study noted two plants, duckweed (*Lemna minor*) and water fern (*Azollafiliculoides*), as particularly suitable, and they grow on the surface of water. The Mars habitat would have to support the conditions of these food sources, possibly incorporating elements from greenhouse design or farming.

Historically, Space missions tend to have a non-growing food supply eating out of set amount of rations like Skylab, replenished with resupply from Earth. Using plants to affect the atmosphere and even enhance food supply was experimented with the 2010's aboard the International Space Station.

Another issue is waste management. On Skylab all waste was put in a big tank; on Apollo and the Space Shuttle urine could be vented out into space or pushed away in bags to re-enter Earth's atmosphere.

Considerations for maintaining the environment in a closed system included, removal of carbon dioxide, maintaining air pressure, supply of oxygen, temperature and humidity, and stopping fires. Another issue with closed system is keeping it free from contamination from emissions from different materials, dust, or smoke. One concern on Mars is the effect of the fine Martian dust working its way into the living quarters or devices. The dust is very fine and accumulates on solar panels, amongst other surfaces.



A Mars habitat in conjunction with other surface elements on Mars (artwork)

Relevant technologies

Some possible areas of needed technology or expertise:

- 3D Printing
- Mars atmospheric entry
- Caves of Mars Project

- Mars Excursion Module
- Aerospace engineering
- Space capsule
- Plants in space

Project task context

A Mars habitat is often conceived as part of an ensemble of Mars base and infrastructure technologies. Some examples include Mars EVA suits, Mars rover, aircraft, landers, storage tanks, communication structures, mining, and Mars-movers (e.g. Earth-moving equipment).

A Mars habitat might exist in the context of a human expedition, outpost, or colony on Mars.

Architects are expected to:

- propose a solution to Mars habitat for human beings taking into account all aspects listed in this document;
- do technical (architectural) design (2D, 3D) of the habitat with accompanying explanations of habitat segments;
- demonstrate an understanding of the specifics of the task.

Due to the specificity of the task, the Architect has all the freedom of creativity. If possible, the proposed habitat model will be physically made (3D printed) in the appropriate size, by the КРСП/CSPD, for easier display and explanation to third parties in Serbia and the World. The proposed habitat model will present Serbia at international exhibitions (EXPO) and Space events through КРСП/CSPD programs. With the proposed model, the Architect will be able to participate in other international Calls/Competitions through КРСП/CSPD programs. The КРСП/CSPD will provide adequate media coverage in the country and abroad for all participants in this Call, i.e. the proposed works.All works will be published as a contribution of Serbian experts to the progress of mankind in this field. The participants who give the best solutions/designs will inevitably be very well versed in this field and КРСП/CSPD will offer them to become members of the КРСП/CSPD as part of the specific sector.

Comparisons between Earth and Mars

Gravity and size

The surface gravity of Mars is just 38% that of Earth. Although microgravity is known to cause health problems such as muscle loss and bone demineralization, it is not known if Martian gravity would have a similar effect. The Mars Gravity Biosatellite was a proposed project designed to learn more about what effect Mars' lower surface gravity would have on humans, but it was cancelled due to a lack of funding.

Mars has a surface area that is 28.4% of Earth's, which is only slightly less than the amount of dry land on Earth (which is 29.2% of Earth's surface). Mars has half the radius of Earth and only one-tenth the mass. This means that it has a smaller volume (~15%) and lower average density than Earth.

Magnetosphere

Due to the lack of a magnetosphere, solar particle events and cosmic rays can easily reach the Martian surface.

The atmosphere

Atmospheric pressure on Mars is far below the Armstrong limit at which people can survive without pressure suits. Since terraforming cannot be expected as a near-term solution, habitable structures on Mars would need to be constructed with pressure vessels similar to spacecraft, capable of containing a pressure between 30 and 100 kPa. The atmosphere is also toxic as most of it consists of carbon dioxide (95% carbon dioxide, 3% nitrogen, 1.6% argon, and traces totaling less than 0.4% of other gases, including oxygen).

This thin atmosphere does not filter out ultraviolet sunlight, which causes instability in the molecular bonds between atoms. For example, ammonia (NH_3) is not stable in the Martian atmosphere and breaks down after a few hours. Also due to the thinness of the atmosphere, the temperature difference between day and night is much larger than on Earth, typically around 70 °C (125 °F). However, the day/night temperature variation is much lower during dust storms when very little light gets through to the surface even during the day, and instead warms the middle atmosphere.

In creating a habitat for people, some considerations are maintaining the right air temperature, the right air pressure, and the composition of that atmosphere.

While it is possible for humans to breathe pure oxygen, a pure oxygen atmosphere was implicated in the Apollo 1 fire. As such, Mars habitats may have a need for additional gases. One possibility is to take nitrogen and argon from the atmosphere of Mars; however, they are hard to separate from each other. As a result, a Mars habitat may use 40% argon, 40% nitrogen, and 20% oxygen. (See also Argox, for the argon breathing gas mixture used in scuba diving)

A concept to scrub CO_2 from the breathing air is to use re-usable amine bead carbon dioxide scrubbers. While one carbon dioxide scrubber filters the astronaut's air, the other can vent scrubbed CO_2 to the Mars atmosphere, once that process is completed another one can be used, and the one that was used can take a break.

Mars habitats with astronauts

One unique structural force that Mars habitats must contend with if pressurized to Earth's atmosphere, is the force of air on the inside walls. This has been estimated at over 2,000 pounds per square foot for a pressurized habitat on the surface of Mars, which is radically increased comparedto Earth structures. A closer comparison can be made to crewed high-altitude aircraft, which must withstand forces of 1,100 to 1,400 pounds per square foot when at altitude.

At about 150 thousand feet of altitude (28 miles (45 km)) on Earth, the atmospheric pressure starts to be equivalent to the surface of Mars.

Water and climate

Water on Mars is scarce, with rovers *Spirit* and *Opportunity* finding less than there is in Earth's driest desert.

The climate is much colder than Earth, with mean surface temperatures between 186 and 268 K (−87 and −5 °C; −125 and 23 °F) (depending on the season and latitude). The lowest temperature ever recorded on Earth was 184 K (−89.2 °C, −128.6 °F) in Antarctica.

Because Mars is about 52% farther from the Sun, the amount of solar energy entering its upper atmosphere per unit area (the solar constant) is only around 43.3% of what reaches the Earth's upper atmosphere. However, due to the much thinner atmosphere, a higher fraction of the solar energy reaches the surface as radiation. The maximum solar irradiance on Mars is about 590 W/m² compared to about 1000 W/m² at the Earth's surface; optimal conditions on the Martian equator can be compared to those on Devon Island in the Canadian Arctic in June. Mars' orbit is more eccentric than Earth's, increasing temperature and solar constant variations over the course of the Martian year. Mars has no rain and virtually no clouds,so although cold, it is permanently sunny (apart from during dust storms). This means solar panels can always operate at maximum efficiency on dust-free days.

Global dust storms are common throughout the year and can cover the entire planet for weeks, blocking sunlight from reaching the surface. This has been observed to cause temperature drops of 4 °C (7 °F) for several months after the storm. In contrast, the only comparable events on Earth are infrequent large volcanic eruptions such as the Krakatoa event which threw large amounts of ash into the atmosphere in 1883, causing a global temperature drop of around 1 °C (2 °F). These dust storms would affect electricity production from solar panels for long periods, and interfere with communications with Earth.

Temperature and seasons

Mars has an axial tilt of 25.19°, similar to Earth's 23.44°. As a result, Mars has seasons much like Earth, though on average they last nearly twice as long because the Martian year is about 1.88 Earth years. Mars' temperature regime is more similar to Earth's than all other planets' in the solar system. While generally colder than Earth, Mars can have Earth-like temperatures in some areas and at certain times.

One of the challenges for a Mars habitat is for it to maintain suitable temperatures in the right places in a habitat. Things like electronics and lights generate heat that rises in the air, even as there are extreme temperature fluctuation outside. There can be large temperature swings on Mars, for example at the equator it may reach 70 degrees F (20 degrees C) in the daytime but then go down to minus 100 degrees F (−73 C) at night.

Examples of Mars surface temperatures:

- Average −80 degrees Fahrenheit (−60 degrees Celsius).
- Polar locations in winter −195 degrees F (−125 degrees C).
- Equator in summer daytime High 70 degrees F (20 degrees C)

Soil

The Martian soil is toxic due to relatively high concentrations of chlorine and associated compounds which are hazardous to all known forms of life.

Survivability

Plants and animals cannot survive the ambient conditions on the surface of Mars. However, some extremophile organisms that survive in hostile conditions on Earth have endured periods of exposure to environments that approximate some of the conditions found on Mars.

Length of day

The Martian day (or sol) is very close in duration to Earth's. A solar day on Mars is 24 hours, 39 minutes and 35.244 seconds.

Temporary vs permanent habitation

A short term stay on the surface of Mars does not require a habitat to have a large volume or complete shielding from radiation. The situation would be similar to the International Space Station, where individuals receive an unusually high amount of radiation for a short duration and then leave. A small and light habitat can be transported to Mars and used immediately.

Long term permanent habitats require much more volume (i.e.:greenhouse) and thick shielding to minimize the annual dose of radiation received. This type of habitat is too large and heavy to be sent to Mars, and must be constructed making use of some local resources. Possibilities include covering structures with ice or soil, excavating subterranean spaces or sealing the ends of an existing lava tube.

A larger settlement may be able to have a larger medical staff, increasing the ability to deal with health issues and emergencies. Whereas a small expedition of 4–6 may be able to have 1 medical doctor, an outpost of 20 might be able to have more than one and nurses, in addition to those with emergency or paramedic training. A full settlement may be able to achieve the same level of care as a contemporary Earth hospital.

Effects on human health

Mars presents a hostile environment for human habitation. Different technologies have been developed to assist long-term space exploration and may be adapted for habitation on Mars. The existing record for the longest consecutive space flight is 438 days by cosmonaut ValeriPolyakov, and the most accrued time in space is 878 days by Gennady Padalka. The longest time spent outside the protection of the Earth's Van Allen radiation belt is about 12 days for the Apollo 17 moon landing. This is minor in comparison to the 1100-day journey to Mars and back envisioned by NASA for possibly as early as the year 2028. Scientists have also hypothesized that many different biological functions can be negatively affected by the environment of Mars colonies. Due to higher levels of radiation, there are a multitude of physical side-effects that must be mitigated. In addition, Martian soil contains high levels of toxins which are hazardous to human health.

One problem for medical care on Mars missions, is the difficulty in returning to Earth for advanced care, and providing adequate emergency care with a small crew size. A crew of six might have only one crew member trained to the level of emergency medical technician and one physician, but for a mission that would last years. In addition, consultations with Earth would be hampered by a8 to 48 minute time lag. Medical risks include exposure to radiation and reduced gravity, and one deadly risk is a Solar Particle Event that can generate a lethal dose over the course of several hours or days if the astronauts do not have enough shielding. Materials testing has recently been done to explore spacesuits and "storm shelters" for protection from Galactic Cosmic Radiation (GRC) and Solar Particle Events (SPE's) during launch, transit, and habitation upon Mars. Medical preparedness also requires that the effect of radiation on stored pharmaceuticals and medical technology would have to be taken into account as well.

One of the medical supplies that may be needed is intravenous fluid, which is mostly water but contains other things so it can be added directly to the blood stream. If it can be created on the spot from existing water then it could spare the weight of hauling earth-produced units, whose weight is mostly water. A prototype for this capability was tested on the International Space Station in 2010.

On some of the first crewed missions, three types of medications that were taken into orbit were an anti-nausea, a pain-killer, and a stimulant. By the time of ISS, Space crew-persons had almost 200 medications available, with separate pill cabinets for Russians and Americans. One of the many concerns for crewed Mars missions is what pills to bring and how the astronauts would respond to them in different conditions.

In 1999, NASA's Johnson Space Center published *Medical Aspects of Exploration Missions* as part of the Decadal Survey. On a small mission it might be possible to have one be a medical doctor and another be a paramedic, out of a crew of perhaps 4–6 people, however on a larger mission with 20 people there could also be a nurse and options like minor surgery might be possible. Two major categories for Space would be emergency medical care and then more advanced care, dealing with a wide range concerns due to Space-travel. For very small crews its difficult to treat a wide range issues with advanced care, whereas with a team with an overall size of 12–20 on Mars there could be multiple doctors and nurses, in addition to EMT-level certifications. While not at the level of a typical Earth hospital this would transition medical are beyond basic options typical of very small crew sizes (2–3) where the accepted risk is higher. For consideration, Elon Musk and his SpaceX Corporation are developing their Starship to transport 100 passengers to Mars per journey. SpaceX has produced a user guide, which claims "The crew configuration of Starship includes private cabins, large common areas, centralized storage, solar storm shelters and a viewing gallery." This number of passengers would create the opportunity for a sizable medical crew. Musk has also projected that he will transport 1 million people to Mars by 2150, which, if it were to happen by that date or any time this century, would certainly require building and manning several hospitals.

With a modest number of Mars inhabitants and medical crew, a robotic surgery robot could be considered. A crew member would operate the robot with help via telecommunications from Earth. Two examples of medical-care situations that have been mentioned in regard to people on Mars is how to deal with a broken leg and an appendicitis. One concern is to stop what would otherwise be a minor injury from becoming life-threatening due to restrictions on the amount of medical equipment, training, and the time-delay in communication with Earth. The time delay for aone way message ranges from 4 to 24 minutes, depending. A response to a message takes that time, the delay processing the message and creating a reply, plus the time for that message to travel to Mars (another 4 to 24 minutes).

Examples of acute medical emergency possibilies for Mars missions:

- Wounds, lacerations, and burns
- Exposure to a toxin
- Acute allergic reactions (anaphylaxis)
- Acute radiation sickness
- Dental
- Eye (Ophthalmologic)
- Psychiatric

An example of spaceflight related health emergency was the inert gas asphyxiation with nitrogen gas aboard Space Shuttle Columbia in 1981, when it was undergoing preparations for its launch. In that case, a routine purge with nitrogen to decrease risk of fire lead to 5 medical emergencies and 2 deaths. Another infamous Space related accident is the Apollo 1 incident, when a pure oxygen atmosphere ignited in the interior of Space capsule during tests on the ground, three died. A 1997 study of about 280 Space travelers between 1988 and 1995, found that only 3 did not have some sort of medical issue on their spaceflight. A medical risk for a Mars surface mission is how the Astronauts will handle operations on the surface after several months in zero gravity. On Earth, Astronauts must often be carted from the Spacecraft. And then they take a long time to recover.

Physical effects

The difference in gravity may negatively affect human health by weakening bones and muscles. There is also risk of osteoporosis and cardiovascular problems. Current rotations on the International Space Station put Astronautsin zero gravity for six months, a comparable length of time to a one-way trip to Mars. This gives researchers the ability to better understand the physical state that Astronautsgoing to Mars would arrive in. Once on Mars, surface gravity is only 38% of that on Earth. Microgravity affects the cardiovascular, musculoskeletal and neurovestibular (central nervous) systems. The cardiovascular effects are complex. On Earth, blood within the body stays 70% below the heart, but in microgravity this is the not case due to nothing pulling the blood down. This can have several negative effects. Once entering into microgravity, the blood pressure in the lower body and legs is significantly reduced. This causes legs to become weak through loss of muscle and bone mass. Astronauts show signs of a puffy face and chicken legs syndrome. After the first day of reentry back to Earth, blood samples showed a 17% loss of blood plasma, which contributed to a decline of erythropoietin secretion. On the skeletal system which is important to support our body's posture, long space flight and exposure to microgravity cause demineralization and atrophy of muscles. During re-acclimation, Astronauts were observed to have a myriad of symptoms including cold sweats, nausea, vomiting and motion sickness. Returning Astronauts also felt disorientated. Journeys to and from Mars being six months is the average time spent at the ISS. Once on Mars with its lesser surface gravity (38% percent of Earth's), these health effects would be a serious concern. Upon return to Earth, recovery from bone loss and atrophy is a long process and the effects of microgravity may never fully reverse.

Psychological effects
Due to the communication delays, new protocols need to be developed in order to assess crew members' psychological health. Researchers have developed a Martian simulation called HI-SEAS (Hawaii Space Exploration Analog and Simulation) that places scientists in a simulated Martian laboratory to study the psychological effects of isolation, repetitive tasks, and living in close-quarters with other scientists for up to a year at a time. Computer programs are being developed to assist crews with personal and interpersonal issues in absence of direct communication with professionals on Earth. Current suggestions for Mars exploration and colonization are to select individuals who have passed psychological screenings. Psychosocial sessions for the return home are also suggested in order to reorient people to society.

Meteor impacts

Another consideration for Mars habitats, especially for long-term stay, is the need to potentially deal with a meteor impact. Because the atmosphere is thinner, more meteors make it to the surface. So, one concern is that a meteor might puncture the surface of the habitat and thereby cause a loss of pressure and/or damage systems.

In the 2010's it was determined that something struck the surface of Mars, creating a spattering pattern of larger and smaller craters between 2008 and 2014. In this case the atmosphere only partially disintegrated the meteor before it struck the surface.

Radiation

Radiation exposure is a concern for astronauts even on the surface, as Mars lacks a strong magnetic field, and atmosphere is too thin to stop as much radiation as Earth. However, the planet does reduce the radiation significantly especially on the surface, and it is not detected to be radioactive itself.

It has been estimated that sixteen feet (5 meters) of Mars **regolith** stops the same amount of radiation as Earth's atmosphere.

As mentioned, Mars has a weaker global magnetosphere than Earth does as it has lost its inner dynamo, which significantly weakened the magnetosphere—the cause of so much radiation reaching the surface, despite its far distance from the Sun compared to Earth. Combined with a thin atmosphere, this permits a significant amount of ionizing radiation to reach the Martian surface. There are two main types of radiation risks to traveling outside the protection of Earth's atmosphere and magnetosphere: galactic cosmic rays (GCR) and solar energetic particles (SEP). Earth's magnetosphere protects from charged particles from the Sun, and the atmosphere protects against uncharged and highly energetic GCRs. There are ways to mitigate against solar radiation, but without much of an atmosphere, the only solution to the GCR flux is heavy shielding amounting to roughly 15 centimeters of steel, 1 meter of rock, or 3 meters of water, limiting human colonists to living underground most of the time.

The Mars Odyssey Spacecraft carries an instrument, the Mars Radiation Environment Experiment (MARIE), to measure the radiation. MARIE found that radiation levels in orbit above Mars are 2.5 times higher than at the International Space Station. The average daily dose was about

220 μGy(22 mrad)—equivalent to 0.08 Gy per year. A three-year exposure to such levels would exceed the safety limits currently adopted by NASA, and the risk of developing cancer due to radiation exposure after a Mars mission could be two times greater than what scientists previously thought. Occasional solar proton events (SPEs) produce much higher doses, as observed in September 2017, when NASA reported radiation levels on the surface of Mars were temporarily doubled, and were associated with an aurora 25-times brighter than any observed earlier, due to a massive, and unexpected, solar storm. Building living quarters underground (possibly in Martian lava tubes) would significantly lower the colonists' exposure to radiation.

Much remains to be learned about Space radiation. In 2003, NASA's Lyndon B. Johnson Space Center opened a facility, the NASA Space Radiation Laboratory, at Brookhaven National Laboratory, that employs particle accelerators to simulate Space radiation. The facility studies its effects on living organisms, as well as experimenting with shielding techniques. Initially, there was some evidence that this kind of low level, chronic radiation is not quite as dangerous as once thought; and that radiation hormesis occurs. However, results from a 2006 study indicated that protons from cosmic radiation may cause twice as much serious damage to DNA as previously estimated, exposing Astronauts to greater risk of cancer and other diseases. As a result of the higher radiation in the Martian environment, the summary report of the Review of U.S. Human Space Flight Plans Committee released in 2009 reported that "Mars is not an easy place to visit with existing technology and without a substantial investment of resources." NASA is exploring a variety of alternative techniques and technologies such as deflector shields of plasma to protect astronauts and spacecraft from radiation.

Power

For a 500-day crewed Mars mission NASA has studied using solar power and nuclear power for its base, as well as power storage systems (e.g. batteries). Some of the challenges for solar power include a reduction in solar intensity (because Mars is farther from the Sun), dust accumulation, periodic dust storms, and storing power for night-time use. Global Mars dust storms cause lower temperatures and reduce sunlight reaching the surface. Two ideas for overcoming this are to use an additional array deployed during a dust storm and to use some nuclear power to provide base-line power that is not affected by the storms. NASA has studied nuclear-power fission systems in the 2010's for Mars surface missions. One design planned an output of 40 kilowatts; nuclear power fission is independent of sunlight reaching the surface of Mars, which can be affected by dust storms.

Another idea for power is to beam the power to the surface from a solar power Satellite to a rectifying antenna (aka rectenna) receiver. 245 GHz, laser, in-situ rectenna construction, and 5.8 GHz designs have been studied. One idea is combine this technology with Solar Electric Propulsion to achieve a lower mass than surface solar power. The big advantage of this approach to power is that the rectennas should be immune to dust and weather changes, and with the right orbit, a solar power Mars Satellite could beam power down continuously to the surface.

Technology to clean dust off the solar panels was considered for Mars Exploration Rover's development. In the 21st century ways have been proposed for cleaning off solar panels on the surface of Mars. The effects of Martian surface dust on solar cells was studied in the 1990s by the Materials Adherence Experiment on Mars Pathfinder.

In-situ resources

In situ resource utilization involves using materials encountered on Mars (**regolith,** subterranean water etc.) to produce materials needed. One idea for supporting a Mars habitat is to extract subterranean water, which, with sufficient power, could then be split into hydrogen and oxygen, with the intention of mixing the oxygen with nitrogen and argon for breathable air. The hydrogen can be combined with carbon dioxide to make plastics or methane for rocket fuel. Iron has also been suggested as a building material for 3D printed Mars habitats.

In the 2010's the idea of using in-situ water to build an ice shield for protection from radiation and temperature, etc. appeared in designs.

A material processing plant would use Mars resources to reduce reliance on Earth provided material.

The planned Mars 2020 mission includes Mars Oxygen ISRU Experiment (MOXIE), which would convert Mars carbon dioxide into oxygen.

To convert the whole of Mars into a habitat, increased air could come from vaporizing materials in the planet. In time lichen and moss might be established, and then eventually pine trees.

There is a theory to make rocket fuel on Mars, by the Sabatier process. In this process hydrogen and carbon dioxide are used to make methane and water. In the next step, the water is split into hydrogen and oxygen, with the oxygen and methane being used for a Methane-Oxygen rocket engine, and the hydrogen could be re-used. This process requires a large input of energy, so an appropriate power source would be needed in addition to the reactants.

Equipment needed for colonization

Colonization of Mars would require a wide variety of equipment—both equipment to directly provide services to humans and production equipment used to produce food, propellant, water, energy and breathable oxygen—in order to support human colonization efforts. Required equipment will include:

- Basic utilities (oxygen, power, local communications, waste disposal, sanitation and water recycling)
- Habitats
- Storage facilities
- Shop workspaces
- Airlock, for pressurization and dust management
- Resource extraction equipment—initially for water and oxygen, later for a wider cross section of minerals, building materials, etc.
- Equipment for energy production and energy storage, some solar and perhaps nuclear as well
- Food production spaces and equipment.
- Propellant production equipment, generally thought to be hydrogen and methane through the Sabatier reaction for fuel—with oxygen oxidizer—for chemical rocket engines
- Fuels or other energy source for use with surface transportation. Carbon monoxide/oxygen (CO/O_2) engines have been suggested for early surface transportation use as both carbon monoxide and oxygen can be straightforwardly produced by zirconium dioxide electrolysis from the Martian atmosphere without requiring use of any of the Martian water resources to obtain hydrogen.
- Off-planet communication equipment
- Equipment for moving over the surface—Mars suit, crewed rovers and possibly even Mars aircraft.

Possible locations for settlements

Equatorial regions

Mars Odyssey found what appear to be natural caves near the volcano Arsia Mons. It has been speculated that settlers could benefit from the shelter that these or similar structures could provide from radiation and micrometeoroids. Geothermal energy is also suspected in the equatorial regions.

Lava tubes

Several possible Martian lava tube skylights have been located on the flanks of Arsia Mons. Earth based examples indicate that some should have lengthy passages offering complete protection from radiation and be relatively easy to seal using on-site materials, especially in small subsections.

Hellas Planitia

Hellas Planitia is the lowest lying plain below the Martian geodetic datum. The air pressure is relatively higher in this place when compared to the rest of Mars.

Planetary protection

Robotic Spacecraft to Mars are required to be sterilized, to have at most 300,000 spores on the exterior of the craft—and more thoroughly sterilized if they contact "special regions" containing water,otherwise there is a risk of contaminating not only the life-detection experiments but possibly the planet itself.

It is impossible to sterilize human missions to this level, as humans are host to typically a hundred trillion microorganisms of thousands of species of the human microbiome, and these cannot be removed while preserving the life of the human. Containment seems the only option, but it is a major challenge in the event of a hard landing (i.e. crash). There have been several planetary workshops on this issue, but with no final guidelines for a way forward yet. Human explorers would also be vulnerable to back contamination to Earth if they become carriers of microorganisms should Mars have life.

Mars analogs and analog habitat studies

Mock Mars missions or Mars analog missions typically construct terrestrial habitats on Earth and conduct mock missions, taking steps to solve some of the problems that could be faced on Mars. An example of this was the original mission of Biosphere 2, which was meant to test closed ecological systems to support and maintain human life in outer Space. Biosphere 2 tested several people living in a closed loop biological system, with several biological support areas including rainforest, savannah, ocean, desert, marsh, agriculture, and a living space.

An example of Mars analog comparison mission is HI-SEAS of the 2010s. Other Mars analog studies include Mars Desert Research Station and Arctic Mars Analog Svalbard Expedition.

- Australia Mars Analog Research Station
- Flashline Mars Arctic Research Station
- MARS-500
- Concordia Station

The ISS has also been described as a predecessor to Mars expedition, and in relation to a Mars habitat the study importance and nature of operation a closed system was noted.

At about 28 miles (45 km, 150 thousand feet) Earth altitude the pressure starts to be equivalent to Mars surface pressure.

Suggestions so far

https://www.archdaily.com/959087/architecture-on-mars-projects-for-life-on-the-red-planet

How to participate / Deadline

1.) Please send your data:
**Your full name (for individual participants) or full names of all members (for team participants),*
**Affiliation (if any),*
**Why you want to participate?*
to our email to inform us that you are interested in participating: **cspd.office@gmail.com**

2.) You can start working on the design;

3.) When you finish your design, please contact us by email: **cspd.office@gmail.com** to agree on how you will send us your work (file/s size matter) and how you will present your work. The plan is to hold a Conference in Novi Sad or КРСП/CSPD's Aerospace center at Airport "Veliki Radinci" where all participants would present their works and a decision on the best design/s will be made by the jury;

4.) Deadline to finish the design: **31st December 2022**

Contact / Responsible organizer

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