Mars Habitation: Design for extreme condition

Abstract

We landed on the Moon a little less than fifty years ago, and human beings will potentially colonize a second planet in near future. The most possible option is Mars. NASA and some private organizations are presently planning to send human missions to Mars within 2030s. Rather than just setting down a simple footprint, however, this will be a more advanced step: the establishment of a successful and durable habitat on the Martian surface. Humankind has an enduring history of survival and adaptation. Considering the advancements made via science and engineering technology, experts already believe that survival on a distant planet is possible – even within a hostile environment such as Mars. Yet, survival is not enough to declare a habitat as successful one. Especially on Mars, it is difficult to ensure a healthy environment for both physiological and psychological conditions within a confined habitat. Perhaps, the most arduous challenge will be to create (or recreate) the feeling of a 'Home' where our human crews will not just survive but will in fact thrive!

This paper explores an overall portrayal of the extreme environmental conditions of Mars and the obstacles to be faced by those first human crews. Finally, through the case studies and their cross analysis, this research will reveal the plausible solutions for the most challenging problem regarding the first Martian habitat : How architecture can construct a viable and sustainable shelter for an extremely hostile environment and simultaneously, establish a new identity for the 'Universal Home' on another planet.

Key words: Mars habitation, Extreme environment, Construction on Mars, Universal home.

Introduction

"He who will one day teach men to fly will have moved all boundary-stones; all boundary-stones will themselves fly into the air to him, he will baptize the earth anew – as the weightless"

Friedrich Nietzsche, Thus Spoke Zarathustra
(1883 – 1885) [1]

I do not think Friedrich Nietzsche thought about inter planetary flying here, however, his words "moved all boundary-stones" reflects human beings present and future curious and passionate steps to the world of unknown. Designing for Outer Space (above the atmosphere) is not the thing architects usually do. At present, we know how to survive in space (near Earth's orbit) and the next step will be how to live on a neighbor planet. Between the two nearest possible options – Mars and Venus, Mars is more suitable for human colonization. The focus of this paper concerns 'MARS Habitation – in an extreme environmental condition'. Therefore, questions arise concerning the category of the habitation on Mars: will it be a temporary or a permanent solution, what types of extreme environment do we need to consider for protection, how should we approach design for this protection, what are the most suitable building materials and what will be the construction process? Finally, what will be the psychological effects on those inhabitants? Overall, what can architecture do to solve these problems? In this paper, I will try to find the answers of these questions trough two hypothetical case studies ("The Ice House" by Clouds Architecture and "The Modular Habitat" by Foster and Partners) along with two existing examples of International Space Station and a research station in Antarctica.

Methodology:

A comparative case study analysis of "The Ice House" by Clouds architecture and "the Modular Habitat" by Foster and partners is conducted to find suitable answers to hypothetical and existing built environments with approximately similar conditions: near orbital space stations and polar area shelter in extreme climatic zone. In addition, through a discussion of the technical (alien climate, hostile nature inclusive of radiation and gravity, construction materials and process) and non-technical issues (living indoor with low atmospheric pressure, psychological effects, and design form and concept) and a cross analysis of these case studies, I hope to arrive at a better understanding of the challenges of mars habitation. Finally, I shall propose the plausible design strategies for designing a habitat in Mars.

Why Mars?

Earth is similar to its "sister planet" Venus in bulk composition, size and surface gravity, but Mars's similarities to Earth are more compelling when considering colonization. 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. Mars has a surface area that is 28.4% of Earth's, 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. Mars has an axial tilt of 25.19°, similar to Earth's 23.44°. As a result, Mars has seasons much like Earth, though they last nearly twice as long because the Martian year is about 1.88 Earth years. The Martian North Pole currently points at Cygnus, not Ursa Minor like Earth's. Recent observations by NASA's *Mars Reconnaissance Orbiter*, ESA's *Mars Express* and NASA's *Phoenix* Lander confirm the presence of water ice on Mars.

Who will go to Mars?

To design the first habitat on Mars, the main consideration will be – who will use it? In other words, who will go to Mars? Both NASA and some other private organizations (like, Space-X and Mars One) are planning to send Manned mission to Mars and their target year is around 2030. However, there is a basic difference in their strategies. NASA is planning to send a small group of astronauts cum scientists, who will land on Mars, stay for a while and come back. On the other hand, these private organizations are planning to send some selected and trained common people to stay there forever. Eventually the habitat design for these two groups will be quite different from each other. Personally, I believe, we need to wait to send a one way manned mission to Mars until a successful return mission is completed as planned by NASA. Therefore, in this paper, I will discuss about the habitat, which will be suitable for staying on Mars for a limited period of time and after that can be reused as a base for the next permanent habitat.

However, no matter which group will go to the Mars first, each person of every group will be well trained and tested for several times both physically and mentally. As Physician Jerri Nielson (a legend of ultimate survival in a life and death situation in Antarctica) in her account of living at the Amundsen-Scott South Pole Station writes, *"living in extreme conditions requires a flexible intelligence, where the ability to quickly absorb and react to new situations is a valuable asset. They wanted to weed out people with personality disorders, chronic complainers, the chronically depressed, substance abusers…"* [2] [Nielsen with Vollers, Ice bound] Yet, we are able to lessen the extremities of physical and psychological sufferings through our concerned architectural solutions, as the following discussion suggest a means to do so.

The Technical Problems: Means of Survival

The technical problems for creating a proper habitat on Mars can be addressed with two fundamental questions: How this habitat will protect us from the alien environment of Mars, which is hostile to humans and how are we going to construct it? In terms of protection, this habitat will be the most protected one we have ever built. Here, the major considerations will be solar and cosmic radiation, extremely cold temperature (the mean surface temperature of different locations of Mars varies from -124.6° F to 23° F, while the lowest temperature ever recorded in Earth was 135.76° F in Antarctica), low atmospheric pressure. According to Stefen L. Petranek, *"On Earth, we live under a very tall pile of atmosphere….. That atmosphere, on average, weighs 14.7 pounds per square inch at sea level. Our bodies push out against the constant pressure. On Mars, where the atmospheric pressure is less than one one-hundredth that of Earth, no human could live long without a pressure suit to match the outward push of the body.")* [3] [Petranek, How We'll Live on Mars] and an air controlled interior to keep oxygen level steady *("Martian air has a partial pressure of CO2 of 0.71 kPa, compared to 0.031 kPa on Earth. CO2 poisoning (hypercapnia) in humans begins at about 0.10 kPa. Even for* *plants, CO2 much above 0.15 kPa is toxic. This means Martian air is toxic to both plants and animals even at the reduced total pressure)"* [4] [Coffey, Jerry (5 June 2008). "Air on Mars". Universe Today. Retrieved 2014-03-02]

Although, it is not an easy task to solve all these problems, with the help of modern science and construction technologies we are able to solve them in several ways. However, when we think about the construction process on Mars, the fields of possible solutions become narrower. Option one – the spaceship carrying the astronauts/scientists from Earth to Mars can be their habitat (which will be both costly and uncertain. Because, the larger the ship the bigger the cost and there is no certainty that the ship will not be damaged after this long journey and the hard landing on the Mars surface.) Option two – the habitat can be constructed prior the arrival of the first human being on Mars using 3D printing technology and specialized robots (which is definitely costly and depends on too much technological perfection in absence of direct human supervision. It will also open up the question of material selection – what will be the suitable local (Martian) building material? Obviously, it will not be an economical solution to transport all the materials from Earth to Mars.) Besides these two options, the third one can be a suitable combination of the first two options. Later in this paper, I will discuss this option with a hypothetical example of "Martian Ice House" in case study section.

The good thing is before finding out the most suitable option, NASA is not going to send any human soul on Mars, which means that it needs to be ensured maximum survival possibilities beforehand. However, that cannot assure a complete successful mission. Simply because, survival is not equivalent of living. Human being has a great survival history through generation to generation. We can adopt with any extreme environment and difficult situation (Human being knows how to survive in a desert, under ocean water or freezing polar areas. we have survived thousands of war, natural disaster, famine or epidemic of lethal disease). There is no doubt that our species are quite able to make this long journey to Mars and survive in that alien environment with the help of appropriate technical support. However, the question is - how long a human crew will remain properly functional to complete a successful mission without a 'Livable

Habitat'? The other name of this 'Livable Habitat' is 'Home'. Therefore, it is time to consider this big issue – How can we create a 'Home' on Mars?

The Home on Mars

Home on Mars is a difficult concept to define. Even on Earth, the concept varies from person to person with different cultural background or from different geological location. Still the common component in everyone's very unique definition of home is 'comfort'. As Juhani Pallasmaa states, *"The experience of home is essentially an experience of warmth. The space of warmth around the fire place is the space of ultimate intimacy and comfort. A sense of homecoming is never stronger than seeing a light in the window of a house in a snow-covered landscape at dusk; the remembrance of its warm interior gently warms one's frozen limbs. Home and skin turn into a single sensation."* [5] [Pallasmaa, An Architecture of Seven Senses] Here it would be important to point out the Pallasmaa is writing from a northern European conception of home that is closely tied to that culture and climate. The conception of home for an another climate and culture will be radically different, but in each case the imagery and physical sensations will support physical and psychological comfort. Basically, our concept of home mostly depends on this psychological comfort zone, which is a complex combination of memory and personal touch. As physician Jerri Nielsen described in her autobiography *"Home – what a concept. I was forty-six years old and living in my parents' house, sleeping in a bedroom decorated with the ruffle curtains and daisy wallpaper of my teenage years."* [6] [Nielsen with Vollers, Ice bound] So, on Earth we can recreate the appearance of home with specific decoration and rearranging our personal belongings according to our own choice to some extends, no matter we live in a foreign country or in a remote place like the research stations of Antarctica or of any desert. However, it is hard to recreate the 'feelings of home'. This special 'feelings of home' represents one's very personal psychological state, which contents not only the physical existence of a house, but also all the surrounding environments where the house exists along with the complex web of passed time. Thus, every individual's concept of home has a singular physical and psychological existence that is intangible even here on Earth. Therefore, how will we perform this nearly impossible job (creation of home) on an alien planet like Mars, where, even one small bedroom for each astronaut will be considered as an ultimate luxury? In addition, how is it possible to create a universal homelike environment, when each member of the small group of astronauts/scientists may have different taste, cultural background and therefore a different concept of home?

Fortunately, this selected group of people for the first manned mission to Mars will not be extreme level of home sick, as they will be tested and trained (both physically and psychologically) for several times beforehand. Still, we do not know how long they will be able to keep their controlled mental strength in any kind of unknown/unpredictable situation during their journey and stay on Mars. At least, we should ensure a psychologically healthy environment for the known/predictable difficult situations, so that they can perform with full mental strength at time of unknown emergency. To do so, first we need to identify the problems/difficulties they will face in normal situation and then go for the possible solutions. Here are some questions for which we are searching the suitable answers:

How we will solve the loneliness of those astronauts? How we can make sure that they will not be depressed or stressed at that hostile planet? How we can provide them the memory of earth's beautiful nature? The astronaut Scott Kelly said in one of his interview that he missed the fresh air mostly, in a way he cannot explain, while there was fresh air supply in International Space Station." [7] [Kelly, Interview with CNN] Is it the memory of free flowing earth's fresh air? How we will recover the extreme silence of Mars? In our earth we have never experienced such silence. How will we ensure them the mental calmness when they will miss the chirping of birds, the sound of flowing water, the simple sound of dried leafs or even the familiar noises and patterns of urban life? Are those artificial recorded sounds of CD players will be enough for those situations?

Through an analytical and comparative study of the following case studies, I will try to demonstrate possible design solutions for these questions. I will look at both technical and non-technical aspects. Relative to Survivability, I will identify technical solutions to the habitat construction method, enclosure strategy and materials, defenses against radiation, pressure and gravity, action plans for food and water. Relative to Livability I will assess non-technical solutions to problems of restricted access, limited space, communal and private spaces and connection to one's personal sense of home.

Case Study 1: "The Ice House"

Project type: First prize winner of the 3-D Printed Habitat Challenge Design Competition by NASA.

Architect/team: Space Exploration Architecture and Clouds Architecture

Location: Mars

The proposal uses a lander as the basis of the shelter, containing both private and communal interior spaces. Once in place, an inflatable membrane is used to create an interstitial environment between the outside of the capsule and the Mars atmosphere. Rovers would then extract water from the ice below the surface at Alba Mons and apply it to form a protective skin on the inside of the inflatable environment. This solution will also create a 'backyard' where astronauts can enter using just an oxygen mask.

(Fig:1) Mars Ice House is 3D printed from translucent ice, which shields the crew from radiation and transforms into a glowing beacon in the Martian night.

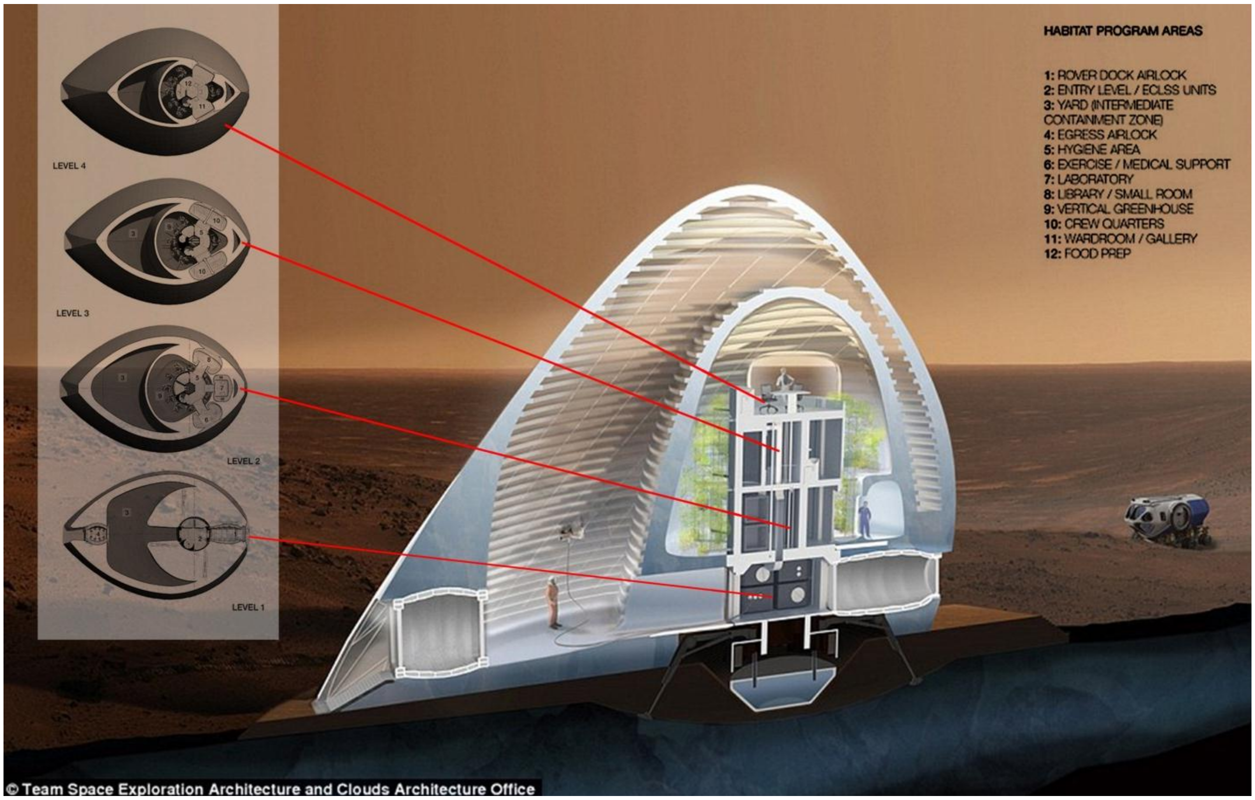


Fig: 2, The sectional perspective with plans of Martian Ice House, edited by me

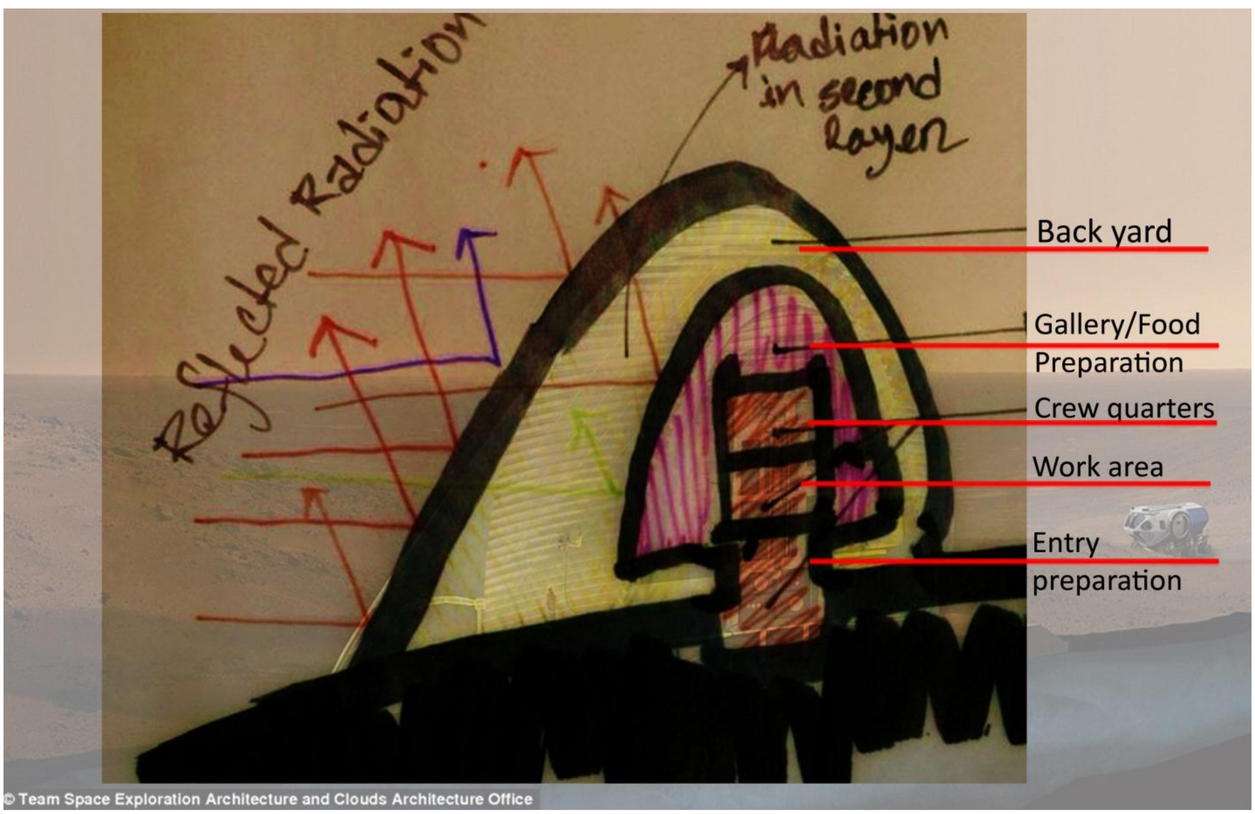


Fig: 3, study sketch by author

The proposal looks very reasonable. However, it raises some questions at the same time: Is "Using the Ice of Mars" to build a house will be a great decision, while the limited iced water has other vital purpose to serve? From the rendering it seems a total contrast with the surrounding: Igloo in a red desert! This may be a good solution for radiation protection and day light. However, the refraction of this heavily layered ice wall will not allow the proper exterior view from inside. Mainly the inhabitants will live in some quarters in the core of the structure. What will be their psychological impact for living in such a small, closed and introvert space for long term basis?

Case Study 2: "The Modular Habitat"

Project type: 2nd prize winner of the 3-D Printed Habitat Challenge Design Competition by NASA.

Architect/team: Team Gamma, architects Foster and Partners

Location: Mars

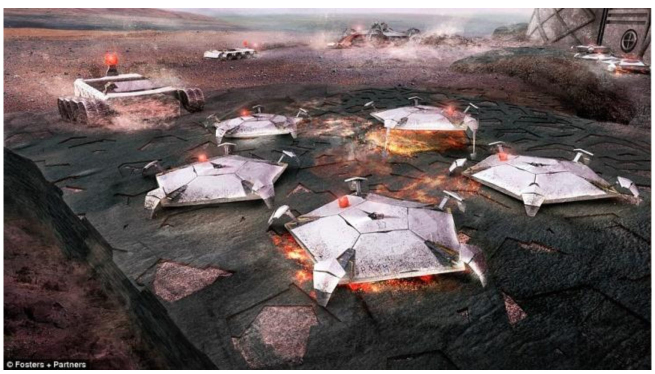
The habitat will be delivered in two stages prior to the arrival of the astronauts. First, semi-autonomous robots select the site and dig a 1.5 meter deep crater. Then the larger 'Diggers' will create the crater by excavating the regolith, which the medium-sized 'Transporters' then move into position over the inflatable habitat modules layer by layer. The loose Martian soil is then fused using microwaves around the modules using the same principles involved in 3D-printing by several small 'Melters'. The fused regolith creates a permanent shield that protects the settlement from excessive radiation and extreme outside temperatures.

In their design Foster and Partners have proposed a solution that is related to our memory of Earth habitation – court yard and the shape of hut. This design is considering the Mars's undulating topography and also the main construction material is primarily very available 'the Mars Soil' (fig: 5)

Step 1

Step 2

Step 3



Final product

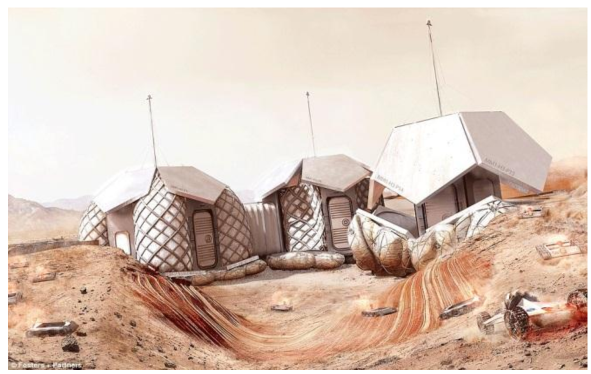


Fig: 4, The Modular Habitat construction steps.

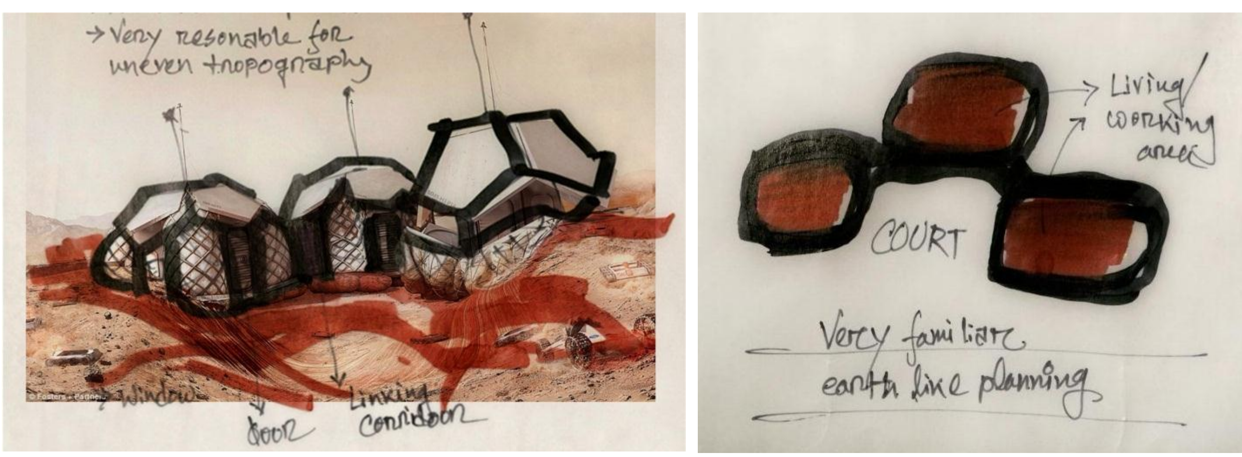


Fig: 5, study sketches by author

Fig: 6, The design of the compact 93 sqm habitat modules combines spatial efficiency with human physiology and psychology, with overlapping private and communal spaces.

In comparison to the Ice house I think this proposal is more sensitive in terms of using materials and merge the habitat with its original natural contest. However, the contraction process is too much dependent on robots, which has to be built first. In addition, the interior rendering is too close science fiction movie set. Is there any necessity to create a 'science fiction type' living space just because the location is Mars?

Though there are provisions for false windows, they are not operable at all, neither functionally nor visually. Windows have great positive impact on human psychology for a small confined space, which is the reason we use the windows in air planes, though it increases the cost of construction. On Mars, to provide the transparency of windows may be more difficult in terms of both safety and cost, however, we can use the digital projection of natural scenes on fake windows to create an illusion of Earth's soothing nature.

Case Study 3: "The International Space Station"

Location: Near orbital of earth

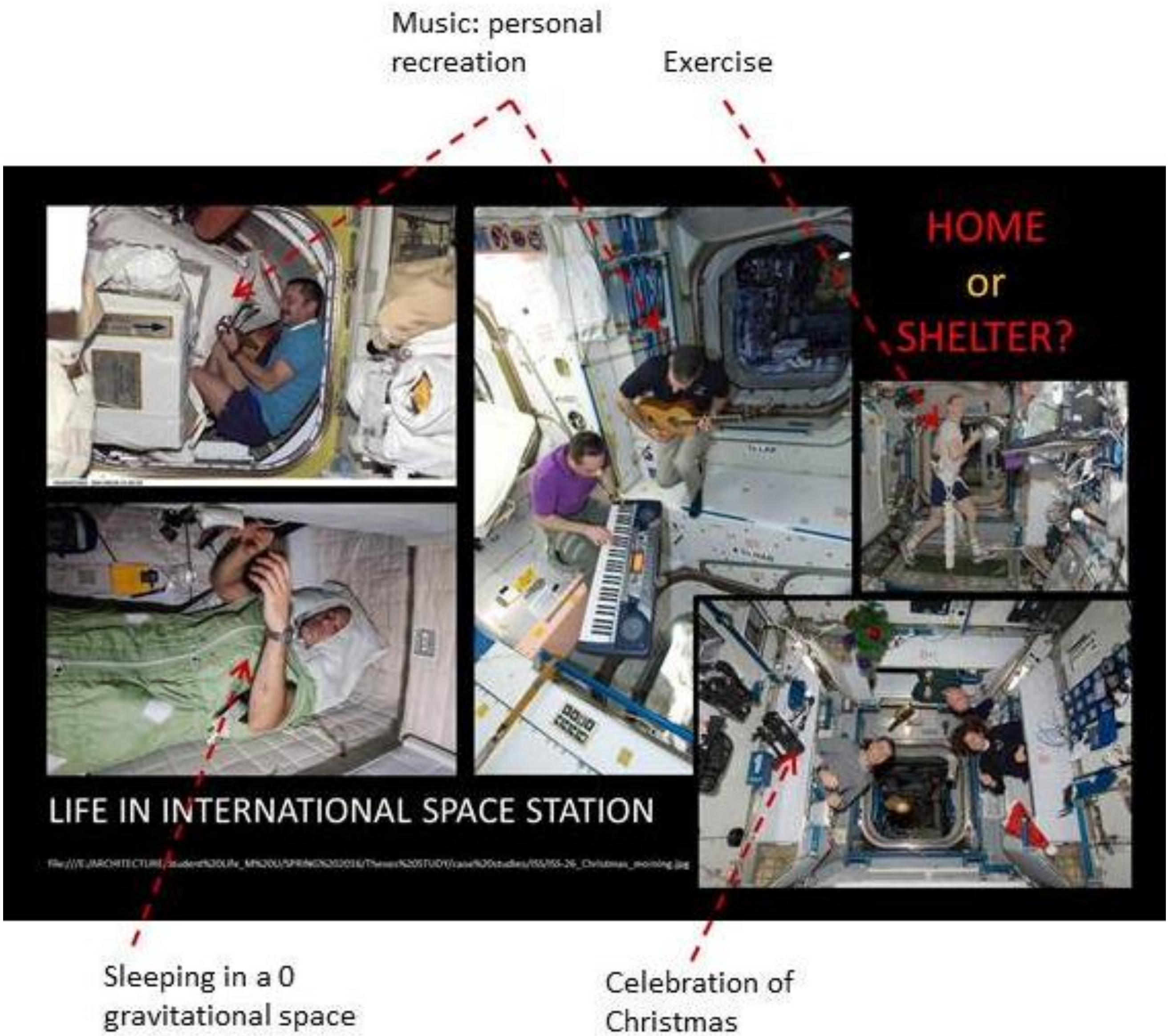


Fig: 7, Human being is in some extend similar in their regular activities or response to life, no matter what differences they have with their cultural background.

Case Study 4: "Atmospheric Research Observatory (ARO) at the South Pole"

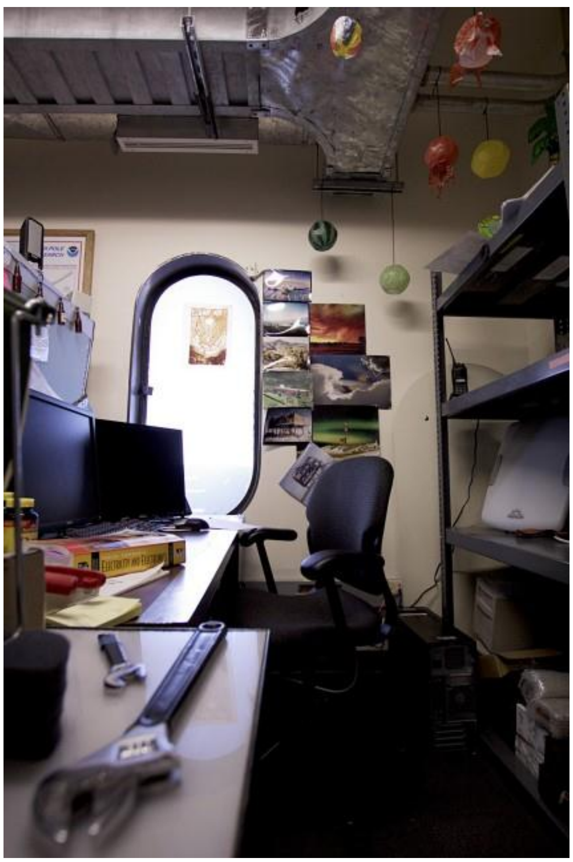


Fig:8, Interior images of Bed room, common area for leisure period and work station of Atmospheric Research Observatory (ARO) at the South Pole.

Though the exterior environment is one of earth's most hostile one, it seems that sleeping quarter, living room and the workstation are quite typical like normal climatic conditions. The furniture and their arrangement, the usage of bright colors, personal belongings and the decoration of the workstation made it home – the universal home, may be!

The case studies I have discussed above are successful shelters when they are out of this planet Earth, but not successful home. Therefore, it is the appropriate time to consider the design factors that will create a successful home and incorporate them in the future space architecture.

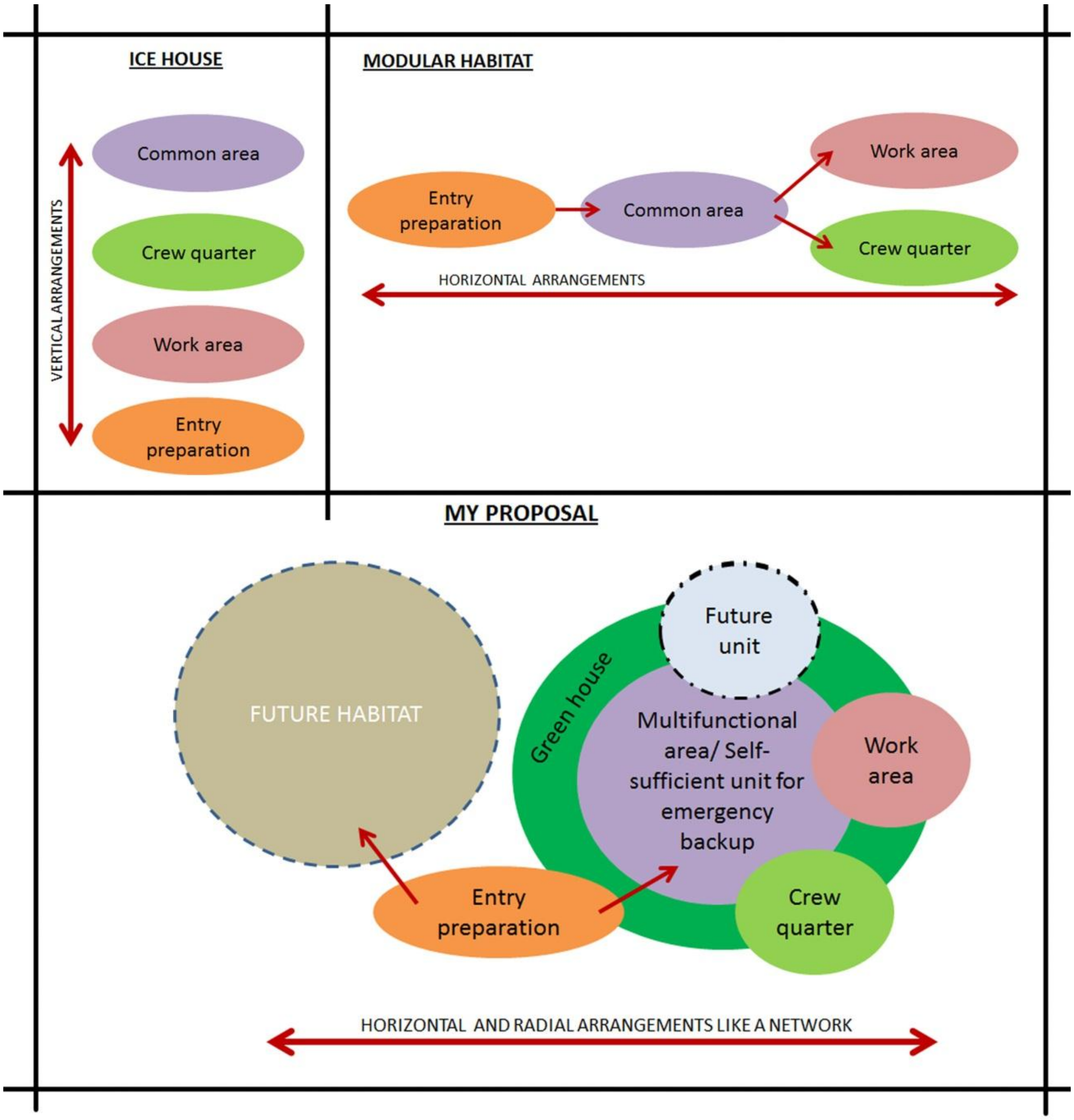
Cross Analysis of Case Studies:

Through these above-discussed case studies, I have tried to portray an overall scenario of what the first human team on Mars will actually experience and what could be a better solution for the future home on Mars. The reason behind selecting two hypothetical case studies and two existing case studies is to compare what we have at present and what we need to improve to transform a space shelter into a home. I have chosen 'The Ice House' and 'The Modular House' as my hypothetical case studies, because they are two completely different type of habitat solutions on Mars with a lot of individual potentialities that can be merged together to create a better one. In addition, I have selected the existing examples of two different locations of extreme environment (International Space Station (ISS) and Atmospheric Research Observatory (ARO) at the South Pole) to understand the difficulties and the dissimilarities between them and the future Martian habitat. Besides, the contrasts between these existing examples are very helpful to recognize what are missing and how to incorporate that missing part to create a Martian home.

However, both the Ice House and the Modular House will be constructed using the 3D printing and inflatable construction technology; the concept, construction method and materials are very different. The Ice House is a vertical solution, which will use the lander as basic structure and the ice wall as a radiation barrier. On the contrary, the Modular House is a horizontal solution, which will be constructed on Mars using the Martian regolith. Using the lander is an economic solution rather than completely robot dependent construction and using the Martian regolith/soil as a main construction material is a reasonable solution in comparison with using ice/water – the most precious substance on Mars. Therefore, why don't we merge these two concepts together to have a better one? The reason behind using ice as a protection wall is to have the transparency and to allow daylight inside the habitat, which is really a good solution for growing plants as well as to have psychologically healthy environment for the inhabitants of a confined space. However, it is also possible to have the same benefits by designing some windows or atriums at proper locations instead of a huge ice dome and thus minimize the usage of Martian water as construction materials. Beside these, the both design solutions do not mention how they are going to solve the psychological issues that will be experienced by the first human team on Mars. That is why I have considered the existing examples to find out how these issues are addressed there as design solutions.

ISS (International Space Station) and ARO (Atmospheric Research Observatory at the South Pole) are completely different to each other except their existence in extreme environments. ISS has the issue with zero gravity and radiation while ARO has to deal with extreme cold only. The Martian habitat will be a combination of these two. Therefore, it is important to consider their good features as well as their lacking to ensure both psychologically and physiologically healthy habitat on Mars. Though both of these science stations have to face the same difficulties with emergency life support supplies from outside, their inside lifestyles are quite different. The ARO has an interior environment, which at least can be described as a universal home, while the ISS is a mess of machineries, which can be depict as an image of a large laboratory, but not in any sense a 'home'. Is it really that much difficult to add some of the ARO features in ISS, only because of zero gravity, or simply we do not consider this yet? If not, it is time to consider this issue seriously and if needed, we have to invent new technology or construction method to create a home on Mars or anywhere outside the Earth.

Functional flow analysis:



Design Strategies:

After the discussion and cross comparison of these four case studies, it is clear that every example has its own powerful characteristics as well as some lacking. However, the combination of these positive criteria of all examples with the addition of those missing criteria can provide us the most efficient design solution for Mars habitat. Based on my above analysis, I am proposing the following design strategies for the first Martian habitat.

Sustainability:

Martian habitat has to be the most sustainable habitat ever built. It needs to be not only less energy consuming but also self-sufficient in energy production. The recycling system for air, water, waste and other materials has to be almost 100% efficient. At the same time, the maintenance needs to keep as minimum as possible within the reach of the crew's expertise. Besides these, the most important consideration will be design every inch in best economic way.

Construction Method and Materials:

The construction method of the first habitat on Mars has to be very easy and simple as well as durable and most efficient. It will be more convenient, if the lander can be used as base of the habitat and then an outer barrier is constructed for the protection from outside extreme environment (Radiation, CO_2 rich thin atmosphere, excessive cold and lethal dust storm). This protection barrier can be constructed on site using the combination of inflatable technology and 3D printing technology. This construction technique will be economic and less time consuming rather than to send a separate mission to Mars with specialized robots only to construct a habitat prior the first human crew's arrival.

Regarding main construction material, it will be wise decision to use local Martian material, which is easy to get and plenty in quantity (like, loose Martian soil or regolith). However, if it needs to carry some materials from Earth, it has to be lightweight and at the same time less space consuming, such as inflatable membrane.

Protection Barrier:

This will be the most important part of the Martian habitat. If there is no protection barrier, human being without a space suit will not even survive for 5 minutes on Mars surface. This protection barrier has to be designed completely airtight with a controlled indoor air pressure. It will also help to keep the oxygen level steady and maintain a comfortable indoor temperature. It will also protect the crews from deadly dust storm and dangerous solar and cosmic radiation. The most challenging issue for this outer barrier will be this radiation control. This barrier must have the ability to reflect back the most dangerous radiations or at least reduce the radiation intensity into a harmless level. Considering this problem, an underground habitat can be a reasonable solution. Here, the more we go into the soil, the more efficient it will be in terms of radiation protection. However, it will be a very costly and time-consuming construction process for the first habitat on Mars due to proper construction machineries and labor. Therefore, we need to go for suitable alternatives with same benefits. One solution may be the 3D printed hollow structure, which can be filled out with loose Martian soil/regolith to get the desired solid depth. Furthermore, some transparent areas will need to be added in this solid protection barrier to allow sunlight for growing crops as well as to create visual connection with outdoor nature. For this purpose, 3D printed ice panel can be one of the possible solutions.

Consideration of Gravity in Design:

Mars has approximately one third of Earth's gravity (Earth: 9.8 m/s^2 & Mars: 3.7 m/s^2). Yet, creating an artificial gravitational field will be less important design issue in comparison with other problems. In fact, this lower gravitational field will be beneficial for the crews to land safely and adjust quickly, after spending more than 1.5 years in an almost zero gravity environment of spaceship. According to Scott Kelly, (the astronaut, who has recently come back after spending 344 days in almost zero/micro gravity environment of ISS) "I felt significantly different coming back. Initially, I felt better coming out of the Soyuz.… After that, I felt much different. *My legs have had kind of a negative reaction to gravity and it's kind of shocking how for the first couple of weeks my legs were swollen, sore, the joints, my muscles, and when I stood up at night I could tell my whole cardiovascular system wasn't used to keeping the blood out of my legs."* [8] [Scott Kelly, March 21, 2016.CNN] Unfortunately, the first human team on Mars has to overcome this phase by themselves without any kind of expert medical help. Luckily, they will face 2/3 less pain or difficulties than the astronaut Scott Kelly has to suffer, because of this 2/3 less Martian gravity than Earth.

However, this gravity needs to be considered to set up a new ergonomics for Martian habitat, especially for determining the height of interior spaces or designing a vertical circulation. Usually, if one can jump up to 3' on Earth, it will be 9' on Mars. Therefore, the height needs to be three times higher than our Earth's standard or at least, double of it. Furthermore, the standard stair case dimensions will not work on Mars. Even, designing a staircase for vertical circulation will not be a wise idea for mars. In this case, besides elevator/escalator simple ladder can be considered like ISS or any spacecraft.

Future Addition and Mobility:

The last, but not the least concern will be design the provisions for future expansion as well as add mobility to some extent. This additive quality needs to be designed in a very smooth way so that a new unit can be added to the old one very easily. This movability feature for whole habitat (or at least for a small self-sufficient part of it) will allow the crews to expand their exploration area beyond the range of a Rover without thinking of coming back to an already explored area.

Interior Spaces:

On Mars, the only place where, the crews will able to do their normal activities without a space suit will be inside this habitat. Besides, the interior spaces of this habitat will be so limited that every square inch of it has to be fully functional and carefully designed. To ensure that the following three issues will be major concern:

1) Most efficient arrangement of different functional areas.
2) Multiple use of a single space.
3) Successful design of illusions.

Arrangements: All the rooms/interior spaces of Martian habitat need to be arranged in the best possible way to get mutual benefits from each other and minimize the circulation areas as much as possible. For example, instead of designing a separate greenhouse for less sensitive plant, the plants can be grown in the common areas, or even inside the living quarters of the crews. It will create a lively interior environment with visual comfort for the crews in a red planet. Another important consideration for this internal arrangement will be to ensure clear distinction between public and private spaces or at least a visual illusion of it so that the crews can get enough privacy for their psychological wellbeing.

Multifunctional Space: This is the most efficient way to minimize the total area of a habitat as well as to minimize the cost. This multifunctional space needs to be designed with a quality to serve properly most of the common functional areas, like- dining, leisure and festivals, exercise, work, library, non-specialized lab and collected sample storage, central communication and so on. In addition, this common space can serve as an emergency backup shelter, if anything happen in the outer protection barrier. For this reason, it has to be designed as a self-sufficient living unit with all necessary life support.

The Illusions: This will be the key feature to create the feelings of home in a Martian habitat. The successful design of illusions using the reactions of human senses will determine the success level of healthy psychological environment as well as better performance. Some important considerations for designing these illusions are - a small space with large appearance, a false window with a real video clip from a crew's home window of Earth, programmed lighting system to create randomly changing weather effect, a pre-programmed sound system with hidden speakers to generate random sounds of Earth's nature and so on. These unexpected randomness and carefully designed illusions will influence a crew's subconscious mind and thus will be a relief in his/her hard monotonous life on Mars.

Conclusion:

After this long discussion and analysis, it is quite clear that constructing a habitat on Mars for an extreme condition is a hard challenge but not impossible. Yet, to transform this habitat into a home exactly as a home on Earth is nearly impossible; simply because every individual has his/her own distinct mental image of home. Even, if we able to recreate that exact mental image for one person, still that house will remain just a house on Mars without that person's family or beloved one around him/her. However, it is not impossible to recreate the universal memories of home by ensuring the physical and psychological comfort. In addition, if we allow the Martian astronauts to decorate their personal space and involve them directly in the construction process of this habitat, it will make them feel that they are building their own house on Mars. Eventually, a new concept of Martian home will take place in their memories.

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