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Martian Mud Huts: The future of Exo-habitation

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Abstract
Mars, our closest planetary neighbour, and the target of mankind's endeavours for exo-habitation poses many challenges to those that wish to inhabit its surface and thus various approaches must be taken to ensure the best chances for colonists. Biodomes might provide the initial habitats however as the colonies grow the use of in-situ materials (regolith) becomes vital. Binder Jet Technology printing with the use of genetically altered bacterial binders might be the key to expansion on Mars.

Keywords: *Earth Sciences; Biology; Microbiology; Exo-habitation; Regolith*

Throughout history man has looked to the stars with the dream to one day travel and live among them. Whilst the vast cosmos is still an inaccessible target, we are slowly edging closer to the colonisation of our solar system. This paper explores the future of exo-habitation (habitation of environments beyond Earth) on our closest planetary neighbour, Mars.

Problems
The Martian landscape is a barren, inhospitable 'desert' devoid of life. This makes colonising the planet extremely difficult. Mars' atmosphere is comprised of 95% CO_2, 3% N_2, 1.6% Ar and trace amounts of O_2, CO, H_2O and CH_4 as well as suspended dust particulates [1]. It should be noted that this atmosphere is extremely thin and whilst the Martian air pressure fluctuates throughout the year, the average 'sea level' pressure is ≈145 times thinner than Earth (6-7 millibars vs 1,013 millibars). This atmosphere presents many obstacles to any habitation efforts. The lack of breathable atmosphere means that any initial colonists will need to constantly wear life supporting spacesuits when outside airtight shelters with sufficient life support. The lack of ozone or similar gases means that the Martian surface is extremely cold and subject to extreme levels of ionising radiation [2] whilst the low external air pressure means that any buildings must be strong enough to contain the high internal air pressure required to sustain a breathable internal atmosphere.

Figure 1 – The Space Analog for the Moon and Mars biodome. An Earth based biodome to replicate the conditions of living on an extraterrestrial body to validate the systems and technologies to be used on the moon and Mars [3].

The average temperature on Mars is -62^{o}C and therefore any structures built to sustain life must be well insulated to prevent hypothermia and provide viable growth conditions for any other organisms introduced to Mars.

It should come as no surprise that getting materials to Mars is extremely difficult due to the distance between the planet and Earth. This is not only due to the time critical nature of any resupply missions but also the tremendous cost associated with them.

Biodomes
Biodomes (figure 1) are a proposed habitat comprised of lightweight materials that are sent to Mars with the first astronauts or to predetermined sites ahead of the first colonists. Biodomes are a promising option for Martian habitats as they can be constructed relatively quickly and customised to the

needs of the colonists and researchers. These biodomes would be constructed from thick plastics and aluminium to withstand the high winds of Martian dust storms and contain the pressurised atmosphere required by its inhabitants.

Biospheres are promising structures for the initial habitation of Mars but face issues regarding temperature, expandability, and radiation. The habitats must be constructed from lightweight materials to reduce the cost of transporting the materials to Mars. This proves a problem for maintaining a comfortable temperature for inhabitants as the insulating properties of these materials are very low and pre-made insulation has a high volume making it difficult to transport to Mars. Likewise, the expansion of biodomes is limited by the time required for new materials to arrive and the amount of materials that can be delivered.

Regolith Printing

Whilst biodomes are effective for the initial arrival on Mars they have many short comings, namely expandability. Due to the difficulty in sending materials to Mars, the use of in-situ materials such as the surface dirt known as *regolith* is highly desirable.

Martian regolith as a building material sees its most promising application as 3D printed bricks. This in-situ resource utilisation is arguably superior to biodomes as fewer materials need to be sent from Earth. Studies using Martian regolith simulants have proved that they can be printed into highly detailed components [4] as well as the high tensile strength bricks [5] required for Martian habitats. The basis of this 3D printing employs binder jet technology (BJT). BJT works by distributing a binder onto a powder bed (regolith), lowering the powder bed, adding more powder, and repeating the process [5]. Once printed the 'green' part is fragile and must be sintered (heated to near melting point of the powder material) to bind the powder into the final product. It has been proposed that different inorganic and organic binders can be used to produce higher quality materials. Using salt water as a binder, the produced bricks fit the criteria for a suitable Martian building material [5].

Regolith based structures can be far larger than early biodomes with greater levels of customisation. The thicker bricks provide greater insulation to the outside temperature. I would suggest the inclusion of intentional surface structures to facilitate the growth of cyanobacteria for oxygen production.

BJT has inherent problems as most binders still need to be sent to Mars and the sintering process has high energy requirements whilst causing sample shrinkage. I propose the use of a biological binder similar to a carbonatogenic bacteria that can produce a strong 'rock like' brick without the need for the sintering process. Carbonatogenic bacteria produce and excrete carbonates. They can be used in biological mortars to bind powdered filler into solid rock [6]. In this application the bacteria would have to undergo serious genetic manipulation to withstand the toxic nature of Martian regolith. This could be achieved using plasmid insertions of extremophile genes such that the bacteria survive in the toxic regolith long enough to solidify the powder into bricks. A bacterial binder has a benefit over other binders as the colonies can be propagated on Mars and therefore less supplies need to be sent into space.

This method may raise concerns about bacterial contamination however the use of cyanobacteria and other life required for exo-habitation arguably negates this risk as contamination of the regolith habitats is inevitable. As such I would suggest the initial biodomes be converted to sterile cleanrooms [7] for any experiments pertaining to 'native' Martian life following standard aseptic techniques to prevent contamination. It should be considered that following the binding of regolith the bacteria will likely die and their calcified remains hold the bricks together, therefore bricks can also be sterilised prior to use. This sterilisation step has lower energy requirements compared to traditional sintering and can be achieved with heat or ultraviolet light.

Conclusion

Exo-habitation is swiftly becoming a possible human endeavour. I believe that using a hybrid of systems (biodomes and regolith printing) a viable Martian colony can be built. Further research into biological binders for BJT processes is required but I think a bacterial solution could have very promising results however as mentioned, extensive genetic modification of these bacteria is required.

References

[1] NASA (2020) *Mars Education | Developing the Next Generation of Explorers*. [online] Asu.edu. Available at: https://marsed.asu.edu/mep/atmosphere [Accessed: 20th March 2024].

[2] Gakis, D. & Atri, D. (2022) *Modeling the effectiveness of radiation shielding materials for astronaut protection on Mars*. Submitted to Life Sciences in Space Research. arXiv:2205.13786v2 [astro-ph.EP] [online] DOI: 10.48550/arXiv.2205.13786

[3] Williams, M. (2021) *Space and Sustainability: How the Lessons of Biosphere 2 Inspired SAM²*. [online] Universe Today. Available at: https://www.universetoday.com/148181/space-and-sustainability-how-the-lessons-of-b2-inspired-sam%C2%B2/ [Accessed: 20th March 2024].

[4] Jakus, A.E., Koube, K.D., Geisendorfer, N.R. & Shah, R.N. (2017). *Robust and Elastic Lunar and Martian Structures from 3D-Printed Regolith Inks*. Scientific Reports, 7(1). DOI: 10.1038/srep44931.

[5] Warren, P., Raju, N., Ebrahimi, H., Krsmanovic, M., Raghavan, S., Kapat, J. & Ghosh, R. (2022). *Effect of sintering temperature on microstructure and mechanical properties of molded Martian and Lunar regolith*. Ceramics International, 48(23), pp.35825–35833. DOI: 10.1016/j.ceramint.2022.07.329.

[6] Betley, C.S.A. (2024). Carbonatogenesis at the Crag: Can bacteria repair rock scarring? *Journal of Interdisciplinary Science Topics*, vol 11 [online]. Available at: https://journals.le.ac.uk/ojs1/index.php/jist/article/view/4619 [Accessed: 20th March 2024]

[7] Angstrom Technology. (n.d.). *WHAT IS A CLEANROOM?* [online] Available at: https://angstromtechnology.com/what-is-a-cleanroom/ [Accessed: 20th March 2024]