The Role of Space Habitat Research in Providing Solutions to the Multiple Environmental Crises on Earth

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ABSTRACT

The Earth is threatened by several environmental crises related to climate change and depletion of resources. These crises are the result of historic patterns of land use and resource extraction that took advantage of the easily acquired naturals resources of the planet. By contrast space habitats must exist in harsh environments where basic resources are only available through energy intensive chemical process. This requires space habitats to develop technologies that enable them to be very efficient in the extraction and use of the resources needed to support their existence. This paper shows how an organized research program to develop the technology needed by space habitats will provide solutions to the environmental crises endangering the future of human society.

PAPER

1 Introduction

The Earth is currently in the midst of a number of environmental crises (Vitousek, 1997). Freshwater shortages are occurring in many parts of the world from a combination of pollution, overuse by agriculture, expanding urban areas and changing weather patterns (Guppy and Anderson, 2017). Resource depletion is another crisis resulting from both the Earth's expanding population and increasing standard of living (Keane 2017). Climate Change is also impacting agriculture yields and increasing demand for energy for both domestic use due to changing weather patterns (The Royal Society, 2010). The desire to prevent additional climate change means that society is looking to reduce emissions of CO2. Finally, the extinction rate of flora and fauna has greatly increased due to the destruction of habitat by human activities, human population increases and climate change (Ceballos et al, 2010). Together these environmental crises have generated questions about the viability of human society and have many concerned about the future of humanity (Xu, 2019).

Over the years advocates for space development have proposed several arguments on how the settlement of space could provide solutions for Earth's environmental crises (O'Neill, 2000). Beaming energy to Earth from space based solar power, bringing resources to Earth from the Moon and Asteroids have been proposed as ways to compensate for the depletion of Earth's resources (Lewis, 1997, Atul, 2015). Although space based solar power may help in supplying energy to the Earth there are numerous competitive Earth based solutions that may be more viable in the near term. It is also difficult to envision resources from space being available in the near term in the quantities needed to make an impact on depletion except in limited areas. These solutions also require the investment of large amounts of resources, especially financial resources, often at the level only available by government, competing with other government priorities. However, the economic development of space does offer other solutions with the potential to have a significant impact on the world's future.

2 Space habitat research and the Earth's future

The impact of space development on the future of human society will not be the physical resources brought to Earth from space, but the technology that space habitats require (Matula and Greene, 2016). Successful space habitats will need to be self-sufficient, a level of technology that still needs to be developed. These technologies will include large scale water recycling, the ability to recycle materials, to

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extract critical elements from low grade ores and to produce the food needed in limited space with limited resources (Matula and Greene, 2016). All of these technologies have the potential to be solutions to the environmental crisis that human society must resolve to survive into the future. Together these technologies have the potential to greatly reduce the impact of human civilization on the planet Earth while enabling a continued increase in the standard of living for humanity.

Humans in space habitats will require water, just as humans do on Earth. But unlike Earth, water is in limited supply on the Moon and in Cislunar, the first likely location for the development of space habitat. The U.S. Geological Survey reports that the average American uses 77 gallons of water per day for domestic needs (Dieter et al 2016). Since one gallon of water equals 3.79 kilograms that is equal to 291.8 kilograms of water per capita. Of necessity many of the household applications of water on Earth will be greatly modified in space habitats to reduce the daily water requirement, but even so the amount of water needed for space habitats would be substantial just for personal use. But space habitats will also need to grow food which will be basic to their long term sustainability. Many industrial process that would occur in space habitats will also require water. On Earth the agricultural and industrial demand for water is far greater than household demand (Dieter et al, 2016).

This means that water recycling will be a requirement for sustainable space habitats. Astronauts on the International Space Station (ISS) currently recycle 90% of the water used, but the ISS receives most of its food from Earth, eliminating that source of water demand. In sustainable space habitats the rate of water recycling will need to be close to 100% and capable of handling a much larger volume per capita than the ISS because of its use for food production. Rather than recycling for a small group of astronauts the systems developed will need to provide recycled water for the needs of a thousand or more inhabitants of the space habitat, not just for normal household uses but also for agriculture and industrial applications. The technology developed will therefore have multiple applications for solving the emerging shortage of freshwater on Earth (Guppy and Andersen, 2017) by allowing communities on Earth to apply it for their water needs. Instead of communities simply taking ground/river water, doing minimal treatment of it and then releasing it into the river they will be able to use the same water repeatedly, only replacing the small percentage that might be lost from the system. This technology transfer will solve the solve the current water crisis for many communities, especially in arid regions.

Space settlers will also need to be very efficient in recycling other resources than water. The high cost of transport to space habitats, along with limited access to resources, means that even simple materials will be too valuable toss away. As a result self-sufficient space settlements will need to have the technology to recycle most if not all the materials they use. Unlike on Earth where trash accumulates in waste dumps in communities, in space all trash will need to be reprocessed into useful materials. This technology will generate valuable spin-offs that turn community waste dumps into a rich source of raw materials. The recycled materials generated from the processing of waste dumps will reduce the demand for resources produced by mining addressing the crisis of resource depletion.

Although space settlers will satisfy most of their resource needs by recycling, there will still be a demand for new resources to replace materials lost through recycling inefficiencies, expand existing space habitats or to build new space habitats. Often these space settlers will need to depend on low quality ore deposits compared to ore deposits on Earth. New technology will need to be developed to extract the materials needed by space settlers. These technologies will enable the development of previously overlooked ore deposits on Earth along with the potential of reworking the dump piles of existing mines to extracts resources missed with their earlier processing. This will also assist in resolving the resource depletion crisis.

3 Space farming and Earth based agriculture

Perhaps the biggest impact space settlement technology will have on the Earth's multiple environmental crises is in agriculture (Matula and Greene 2016). Space habitats will have limited space to produce the food and will need to advance the technology for food production to achieve agriculture self-sufficiency.

Agriculture accounts for 50 percent of the Earth's habitable land, some 51 million square kilometers (Ritchie and Roser 2019). That is equal to .6 hectare per person, an amount that will not be available in space habitats, not even the large orbital habitats proposed by Gerald O'Neill (2000). Agriculture will need to become much more efficient in land use if it is going to supply the needs of space settlers. Fortunately, there is an emerging technology that provides a possible solution, Controlled Environment Agriculture (CEA). Controlled Environment Agriculture is the next step in securing the human food supply and consists of moving plants into an enclosed environment in which lighting, water, temperature, nutrients and even the CO2 level in the air is optimized for the species being cultivated (Shamshiri, 2018). The water used is recycled within the system, reducing the water demand by up to 95%, critical for resolving the freshwater crisis which is impacting many agriculture regions. Since CEA is independent of seasonal cycles it is possible to produce crops continuedly ensuring a steady supply to markets. The result is a huge increase in crop yields by CEA, depending on the species, over existing agricultural yields (Shamshiri, 2018).

Research, and commercialization, has so far been limited to high value "garden" crops like herbs, flowers, vegetables, and selected fruits. Little if any research has been done on the application of CEA to the staple crops (corn, wheat, rice, etc.) that will be needed to sustain a space settlement, or human society on Earth. Research has also been lacking using plants that produce industrial products like fiber, latex, building materials, etc. The focus of space habitat technology should be on the staple crops, garden crops, and industrial plants. Not only would this provide the foundation of farming in space habitats, but also help resolve the environmental crises of freshwater, climate change, and habitat destruction.

Perhaps the greatest impact of CEA will be on climate change as food production and transportation accounts for an estimate one-third of greenhouse gases (Gilbert, 2012). Because CEA is produced in a controlled environment it is able to use renewable energy instead of fossil fuels for the production of food. It also does not require either pesticides or herbicides because its isolation from the external environment serves as an effective barrier to weeds and insects. Since it is independent of the external environment it is also independent of climate zones, so the facilities for producing the food could be located near the demand for it, eliminating the global shipping of agricultural goods that currently accounts for large amounts of greenhouse gases. Finally, the increased yields resulting from CEA will enable the restoration of tens of millions of square kilometers of land to native ecosystems, a process that will not only reverse the extinction crisis but also provide for the sequestration of large amounts of greenhouse gases from the atmosphere.

4 Conclusion

The research that will be required to build sustainable space habitats will also provide the technology required to build sustainable communities on Earth. Space settlement advocates should advocate and develop a research agenda for space habitat technology with the goal of applying them to solve environmental problems on Earth. The technology developed for recycling water and materials will help resolve the crises in freshwater and raw materials. The adaption of CEA by economies on Earth has the potential to allow nations to reach their climate change goals without requiring a reduction in their standard of living. It will allow tens of millions of kilometers to be restored to native ecosystems resulting in reversing thousands of years of environmental destruction. The application of this technology to address problems on Earth will further advance them through iterative development enabling them to mature to the point where they will be ready to apply to future space habitats. Developing the technology to green the Solar System will also green the Earth for future generations.

ACRONYMS

Acronym	Description
CEA	**Controlled Environment Agriculture**

REFERENCES

Atul, Anveshi (2015). "A Study on Space-based Solar Power System," Journal of Environmental Science, Toxicology and Food Technology, Volume 1 Issue 5, 1-3.

Ceballos, Gerardo, Garcia, Andres, & Ehrlich, Paul R. (2010). "Loss of Animal Populations and Species," Journal of Cosmology, Vol 8, p1821-1831.

Dieter, Cheryl A., Maupin, Molly A., Caldwell, Rodney R. Caldwell, Harris, Melissa A., Ivahnenko, Tamara I., Lovelace, John K., Barber, Nancy L. and Linsey, Kristin S. (2016). "Estimated use of water in the United States in 2015," Circular 1441, U.S. Geological Survey, Washington D.C.

Gilbert, N. (2012). "One-third of our greenhouse gas emissions come from agriculture," Nature, https://doi.org/10.1038/nature.2012.11708.

Guppy, L., Anderson, K., (2017). "Water Crisis Report". United Nations University Institute for Water, Environment and Health, Hamilton, Canada.

Kevin Keane (August 22, 2017). "Earth Overshoot Day: When consumption outstrips the planet's eco resources." Retrieved from https://www.bbc.com/news/uk-scotland-53861858 June 7, 2021".

Lewis, John S. (1997). "Mining the Sky," Perseus Books Group, New York, NY.

Matula, Thomas L. and Greene, Kevin (2016), "The Role of Space Settlement Research in Development of Environmentally Sustainable Technology," in the Proceedings of the ASCE Earth and Space Conference, Orlando, FL April 11-15, 2016.

NASA (2021). "Growing Plants in Space." Retrieved from https://www.nasa.gov/content/growing-plants-in-space June 11, 2021.

O'Neill, Gerald (2000). "The High Frontier: Human Colonies in Space", 3rd ed., Apogee books: Burlington, Ontario, Cananda.

Ritchie, Hannah and Roser, Max (2019). "Land Use," Retrieved from Our World in Data https://ourworldindata.org/land-use June 11, 2021.

Shamshiri, Redmond Ramin, Kalantari, Fatemeh, Ting, K.C., Thorp, Kelly R., Hameeds, Ibrahim A., Weltzien, Cornelia, Ahmad, Desa Ahmad, and Shad, Zahra Mojgan (2018). "Advances in greenhouse automation and controlled environment agriculture: A transition to plant factories and urban agriculture," International Journal of Agriculture and Biological Engineering, Volume 11, number 1.

The Royal Society (2010). "Climate Change: A Summary of the Science," The Royal Society, London, United Kingdom.

Vitousek, P.M., Mooney, H.A., Lubchenco, J., Melillo, J.M. (1997). "Human Domination of Earth's Ecosystems," Science, 277,494-499

Xu, Chi, Kohlerb, Timothy A., Lentonf, Timothy M., Svenning, Jens-Christian, and Schefferc, Marten (2019). "Future of the human climate niche," Retrieved from PNAS from https://www.pnas.org/content/pnas/early/2020/04/28/1910114117.full.pdf June 11, 2021.