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by Sanaul Haque

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Assessing the potential use of solar powered heating satellites for targeted greenhouse warming of the Martian surface

Kelly-Emmanuel Pierre

Charlotte Catholic High-School

Senior (Class of 2026)

United States

epiere2018@gmail.com

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Background:

When determining the human survivability of a planet, many factors are taken into consideration, such as the composition of the atmosphere or the force of gravity. Two of the most important factors are average temperature and liquid surface water. Mars is often referred to as humanity's next home, to the point where astronautical giant SpaceX has fully backed investment and development into Martian colonization. There is, however, a large issue with this goal: Mars, while being the closest planet (besides Earth, of course) to habitability, is still not very suitable for sustained life. The average temperature on Mars is chilly $-\ 65^{\circ}C$ [1]. Mars, though, does have frozen surface water at its poles, and melting this could serve to warm the planet through trapping heat over time, primarily through the warming effects of gaseous H_2O and CO_2.

Research Goal:

This research tries to quantitatively estimate the required minimum sustained active solar flux (W/m) to create a self-sustaining, runaway greenhouse effect on Mars and thus increase its mean global temperature from $-\ 65^{\circ}C$ to a habitable $15^{\circ}C$. The objective is realized through two main aims: Climate and Energy Quantification: Calculate the overall latent heat of sublimation (L) in Joules (J) to vaporize a sufficiently large volume of Martian CO_2 and H_2O polar ice caps to reach the critical atmospheric density required to create a stable, run-on greenhouse effect. Model the required initial atmospheric partial pressures of H_2O vapor and CO_2 needed to provide a net positive radiative forcing (in W/m), which leads to a temperature increase to $15^{\circ}C$. even when active heating is terminated.

Engineering and Deployment Feasibility: Specify the optimal engineered orbital configuration, e.g., a solar orbital concentrator or a mirror system, to supply the needed energy flux to the polar region. Choose an optimal orbital arrangement (like low Mars orbit, areosynchronous orbit, or polar Sun-synchronous orbit) to minimize/ensure maximum illumination uniformity and optimal efficiency of operation. Predict the expected mass and construction duration of the system, along with a complete phase-based plan of attack to deploy it and an overall estimate of the number of years required to reach an expected temperature of 15°C.

Research Questions:

- What is the percentage composition of H_2O and CO_2 in Martian polar ice?
- What is the total energy in joules required to heat a specified amount of polar ice to the point of sublimation?
- What is the most effective engineered orbital solution to achieve the desired effect? Included a feasibility study of each solution.

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Literature Review:

Research into Martian history points to the fact that Mars at one point did maintain liquid water on its surface, and therefore had an average temperature $> 0^{\circ}C$ [3]. The total usable amount of trapped CO_2 may be sufficient for the required heating [3]. Alternative solutions to Martian heating include the controlled release of aerosols into the atmosphere [4] or the use of nanorods manufactured from materials already present on the Martian surface [5]. The latter method is claimed to be 5×10^3 times more effective than the best gases for the same job [5]. Research is lacking on the effectiveness of targeted solar energy transfer from orbit to the surface. The desired run-on warming effect is possible as shown by prior climate simulations [3].

Methodology:

Due to the project's essentially twofold nature, two separate research frameworks would be implemented. The first objective would be to detail the needed energy to induce a run-on effect to gradually raise the surface temperature. To accomplish this, a simplified atmospheric model based on preexisting Martian factors would be used (2-D Radiative-Convective Climate Model) [2]. Following this, the figures for the required gas release would be used to calculate the needed energy to be delivered to the poles over a set period of time. The lessons from this first section of research would then be used to form constraints and criteria, which would go into the development of a variety of potential orbital solutions. The best solution would complete the operation in the lowest continuous timeframe, for the least amount of time, and require the least dedicated R&D/maintenance.

Plan:

- Weeks 1-2:
  - Literature Review, data collection (ice cap volume, thermal properties), and establishing the energy calculation model
- Weeks 3-4:
  - Running climate feedback simulation to determine the minimum gas release required, along with the required power delivery
- Weeks 5-6:
  - Engineering research and development, first concepts
  - Narrowing of experimental concepts
- Weeks 6-7:
  - Final concept chosen, orbital mechanics, technological feasibility study
- Weeks 8-9:
  - Conclusion, final research report, and engineering project outline
- Week 10:

➢ Editing and peer review

Potential Limitations:

The most glaring limitation will be the fact that direct testing of the concepts will be impossible; furthermore, creating accurate models would require extensive trial and error, as there is no established baseline to build off of. Similarly, the engineering aspects will be largely theoretical, as to date, no similar orbital power delivery system has been developed.

Conclusion:

In short, this work aims to provide a quantitatively proven and practical engineering and climatic plan of action for arguably the most important preliminary phase of any Mars terraformation effort: proactive implementation of a self-sustaining greenhouse effect to achieve a habitable temperature of +15°C. The dual-faceted approach, which integrates radiative-convective climate modeling to establish gas release objectives alongside a comprehensive orbital engineering evaluation to satisfy the necessary energy flux, will effectively connect theoretical climate aspirations with their practical implementation. While its engineering implementation is hypothetical due to the historically unmatched scale of orbital power transmission required, the true strength of this undertaking is that it is a matter of known physics (Stefan-Boltzmann, latent heat) and tried and true modeling techniques (2-D radiative-convective models).

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