**Mars terraforming research internships.**

Astera Institute is funding Mars terraforming research. A team in Emeryville, CA is working on basic science and mission design. We also have a team in Chicagoland working on particle design, small-batch manufacturing and testing. The research is led by Edwin Kite (sseh.uchicago.edu), who is a Resident at Astera's Emeryville, CA facility. We are looking for people interested in short-term, paid roles at Emeryville. On-site is preferred, hybrid/semi-remote options are negotiable. Dates are flexible. To express interest, please email your CV and an explanation of which project(s) you are interested in (and why) to edwin.kite@astera.org

This research offers an opportunity to engage with one of humanity's greatest challenges. Specific projects include the following:

*Roles marked "\*" have leadership potential / potential to grow into multi-intern projects in subsequent years.*

**Implementing plume-imaging capabilities (\*).**The engineered aerosols currently considered for terraforming are designed for optical efficiency and typically sub-micron in size. However the clumping of the engineered aerosols into larger aggregates that would be optically inefficient is a significant mission risk that needs to be assessed and possibly mitigated. As a first step toward characterizing clumping rates for the engineered particles, the task will be to implement an imaging system to diagnose the physical properties of a plume from a laboratory-grade mist system. Specifically, the task will be to implement an experimental set-up (such as hyperspectral/thermal camera, spectrometer) and the analysis pipeline to constrain the optical properties and size of the released aerosols.

**Design of a terraforming engine (\*).** So far, calculations suggest that the mass of particles needed to warm Mars is in the millions of tons—too large to be readily shipped from Earth. Manufacturing these particles on Mars is the ultimate in-situ resource utilization challenge. The task is to build a system model for size, weight, and power requirements for particle manufacture (the "terraforming engine") for *either* carbon particles (e.g. graphene nanoplatelets) *or* metal particles (e.g. small Al disks). While feedstock ISRU (i.e., production of C from air, or metals from regolith) is relatively well-quantified, a key task will be to quantify the feedstock-to-particles step.

**Mars-orbiting warming particles.** In principle, particles released into Mars orbit (e.g. from Phobos) can warm Mars. However, solar radiation pressure will raise the eccentricity of particles with a too-small mass-to-light ratio. Engineered particles will (by design) interact strongly with thermal infrared. In this context, a little-considered effect is the anisotropic and time-varying (e.g., seasonal cycle) thermal radiation pressure from Mars. This project is to determine the effect of these nongravitational forces on the orbital lifetime of Mars-orbiting engineered particles at a range of orbital inclinations, in order to guide improved particle design.

**Solar sails for warming Mars.** Solar sails can be flown from high Earth orbit to Mars. Once at Mars, they can reflect sunlight down to Mars' surface (Handmer, Tenth Mars, 2024)—for example, the polar caps. However, the optimal orbits to warm points on Mars' surface, considering that the sun is not a point source, etc., are not known. The task is to find classes of orbits for solar sails that efficiently increase the insolation at a point near Mars' south pole.

**Use climate model output to assess microbial habitability.** Several methods have been proposed to warm Mars (e.g., Ansari et al. Sci. Adv. 2024). However, warmed Mars soil would still pose great challenges for even simple forms of life, including low pressure, potentially low water availability, and high surface UV. This work would use detailed climate model output (generated by other members of the Emeryville team) to simulate where, when, and at what depth(s) microbes might grow within Mars’ soil as Mars warms up.

**General application.** If you have an idea not listed above that can advance the basic science or engineering of Mars terraforming and are ready to pursue it, I want to hear about it! Also, if you are interested in refining a specific aspect of the surface-deployed engineered aerosols proposal (Ansari et al. Science Advances 2024), let me know.