Professorship of Lunar and Planetary Exploration
TUM School of Engineering and Design
Technical University of Munich

Semester Thesis

A parametric study of solar heating methods for thermal ice mining

theoretical / numerical thesis
Start date: As soon as possible / summer semester 2025

Topic:

Water is one of the most accessible and abundant resources in the solar system. The presence of water has been detected on the lunar surface and asteroids, both promising target destinations for thermal ice mining. Combining this with Water-Electrolysis-Propulsion (WEP) technology can form the basis of a self-sufficient space mobility architecture. The extracted and purified water is electrolysed on board of a spacecraft into hydrogen and oxygen, which are subsequently supplied to chemical, cold-gas, or electrical thrusters. Within the scope of the project "Ice to Thrust", the Professorship of Lunar and Planetray Exploration collaborates closely with the Chair of Space Mobility and Propulsion to demonstrate the combined process chain (water extraction, electrolysis, and thrust generation) for the first time on laboratory scale.

Below its triple point, water can only exist as ice or gas which has unique implications for the extraction process. Different heating methods can be used for process step 1 in Fig. 1. Two main candidates for closer investigation with the Ice to Thrust project are solar surface heating and microwave heating. In later project stages, the thermal extraction will be investigated experimentally.

To aid the design of the vacuum facilities, this thesis shall develop a transient 3D simulation of the solar surface heating process, ice sublimation and transport of water vapour. Similar simulation cases were already performed at the research group with the software package COMSOL Multiphysics. A parametric simulation study shall vary parameters such as sample size, water content or input power to characterize the extraction process and provide boundary conditions for the design of the remaining facility (vacuum pump rates, sample cooling, cold trap).

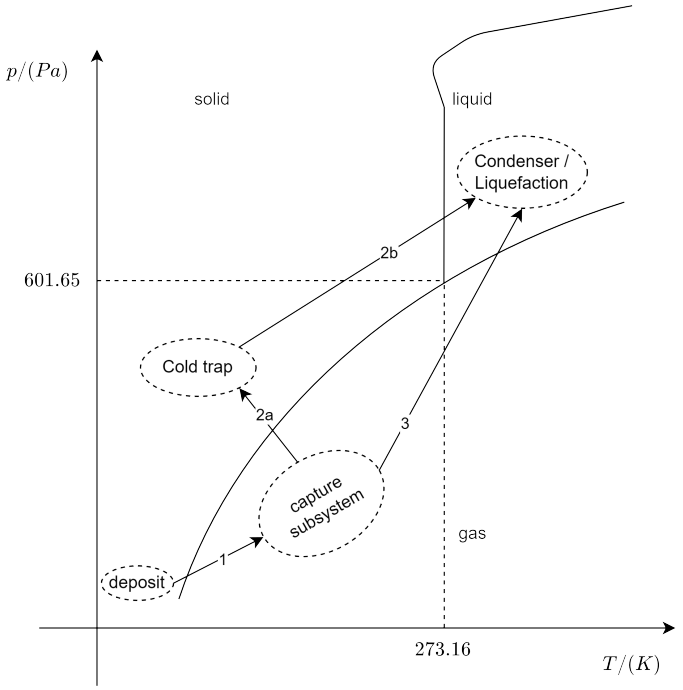

Figure 1: Thermal ice mining process in the water phase diagram.

Tasks:

- research and summarize previous work on regolith heating methods
- build a simulation model of heat and mass transfer of a regoloith sample in COMSOL
- define performance metrics (e.g. temperature uniformity, water extraction rate, energy efficiency, or similar) for a systematic comparison of heating methods and sample geometries
- perform parameter studies of a (laboratory-scale) solar surface heating case
- analysis and discussion of the results

Recommended Literature:

- Successful completion of the module "Space Resources"
- Heitkamp, M. (2024): *Lunar Water Extraction: Design, Optimization, and Development for Future Space Exploration*. Master´s Thesis. University of Twente. Available online.
- Kiewiet, L. et al. (2023): *Design Investigation of Lunar Water Extraction*. Space Resource Week 2023, Luxembourg. Available online.
- Purrington, C. et al. (2022): *Thermal Mining of volatiles in lunar regolith simulant*. Plantary and Space Science 222:105550, DOI: 10.1016/j.pss.2022.105550
- Wasilewski, G. (2021): *Lunar thermal mining: Phase change interface movement, production decline and implications for systems engineering*. Planetary and Space Science 199:105199, DOI: 10.1016/j.pss.2021.105199

Requirements:

- basic knowledge and interest in lunar and planetary exploration
- knowledge in heat and mass transport as well as thermodynamics
- experience with COMSOL is considered an asset
- programming skills, preferably in Julia, Matlab, and/or Python
- motivated, pragmatic, and self-organized personality
- good command of the English language

NOTE: Please read our general notes on student theses and project works listed on our website:
https://www.asg.ed.tum.de/en/lpe/teaching/theses/

Supervisor:

Thilo Witzel

Postal address
Lise-Meitner-Straße 9
85521Ottobrunn

Contact
Phone: +49 (89) 289 - 55790
thilo.witzel@tum.de