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## Project Objective

Design and development of experimental hard-ware to transport sublimated water vapor from thermally mined lunar regolith using electrostatic field and to characterize ice collection rates in an engineered cold trap.

## Introduction

The ongoing Lunar Resource Development project between NASA Johnson Space Center and UTEP cSETR is focused on the design and development of engineered vapor transportation and collection technologies from icy lunar regolith. The existing thermal mining technologies exhibit low vapor pressure and high temperature sublimation, therefore, it becomes difficult for the rarefied vapor to transport and separate from other volatiles. Moreover, the poor thermal conductivity of ice reduces the heat transfer rate, i.e., accumulation rate, during continuous collection in a cold trap. Therefore, this work presents an integrated vapor ionization and intermittent ice delamination system for advanced lunar ice collector.

## Project Concept

In order to capture ice from lunar regolith, this work presents an engineered vapor separation and transportation using electrostatic field-induced pathway, and a continuously ice re-capture technology in an active cold trap that utilizes heat pipe evaporator walls as ice collector plate embedded with a thin film negative electrode to attract the ionized vapor molecules, and a thin film vapor generator for intermittent delamination of ice. Figure 1 presents cSETR advanced thermal mining concept.

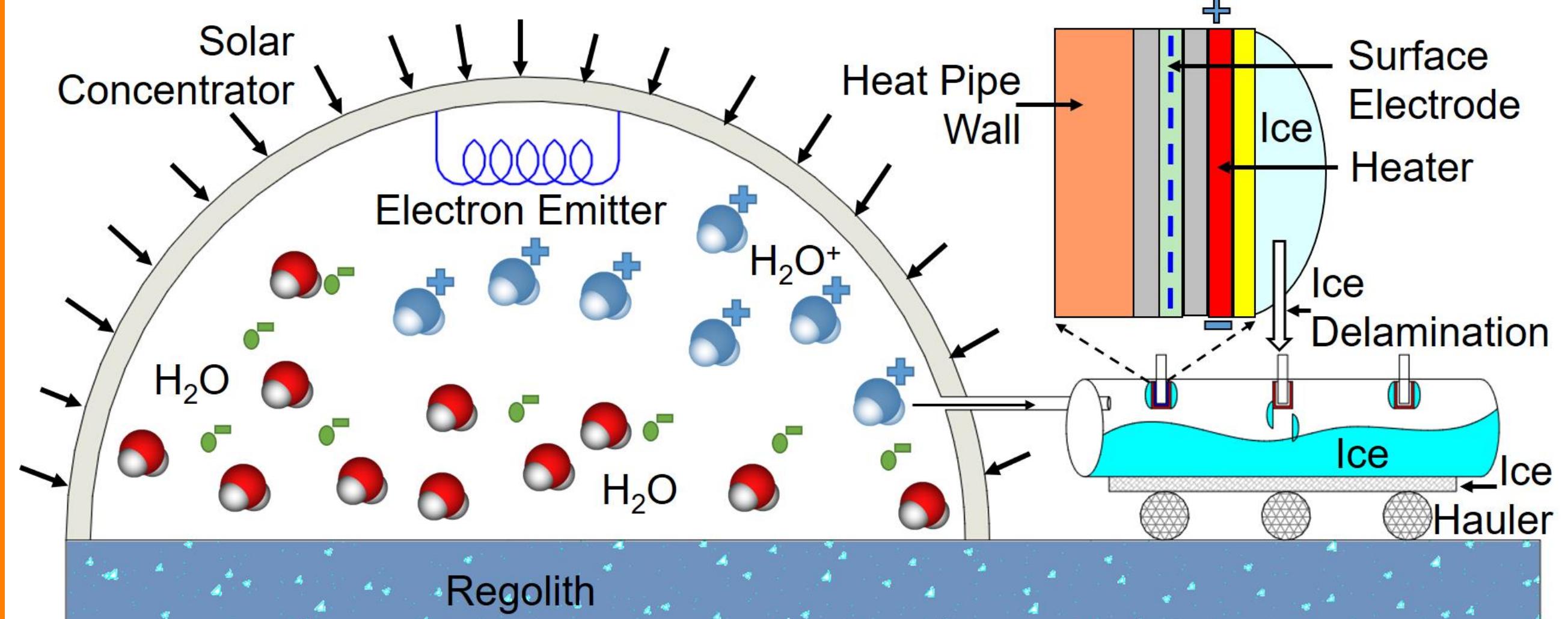


Figure 1. Schematic of cSETR advanced thermal mining concept utilizing vapor ionization and collection systems

## Acknowledgments

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## Electrostatic Transportation of Vapor

This task focuses on the vapor ionization and transportation of the water vapor sublimated from LMS-1 simulant to the condenser chamber. Experiments are performed in the cSETR Thermal Vacuum (T-Vac) chamber (Fig. 2a) at  $10^{-5}$  Torr base pressure and  $-120^{\circ}\text{C}$  temperature. Studies of ionization transport methods will take place in T-Vac using the setup depicted in Fig. 2b. Patch heaters underneath a wetted lunar regolith sample controls water vapor sublimation rates. A tungsten filament is used as the electron emitter, two biased copper plates are used to produce a constant electrostatic field for ion acceleration, and a Langmuir probe is used to measure the ion density.

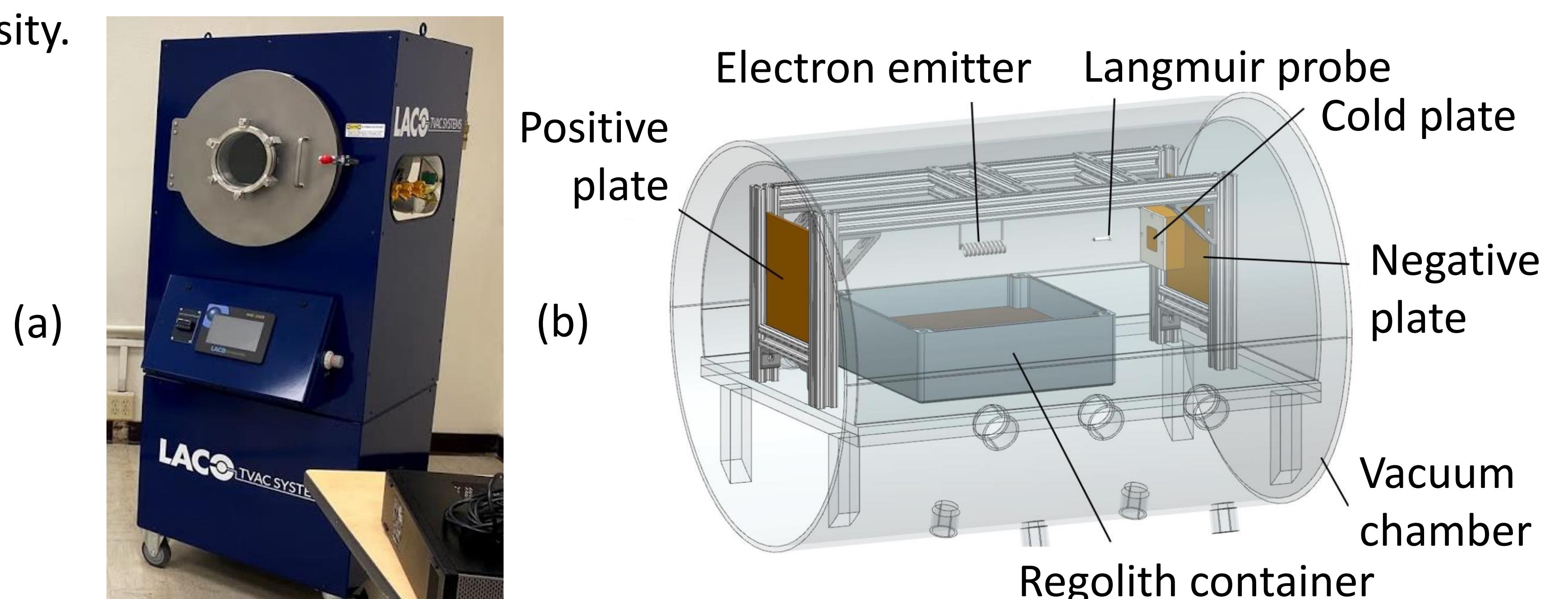


Figure 2. (a) cSETR T-Vac, and (b) ionization transport experiment set-up

## Engineered High Capacity Cold Trap

The high capacity engineered cold trap focuses on developing a space-qualified engineered cryogenic heat pipe and collecting ice in a cold trap from lunar regolith during thermal mining. A custom-built cold plate (up to  $-130^{\circ}\text{C}$ ) and ice collector at cryogenic vacuum environment are used to identify the rarefied vapor deposition fundamentals.

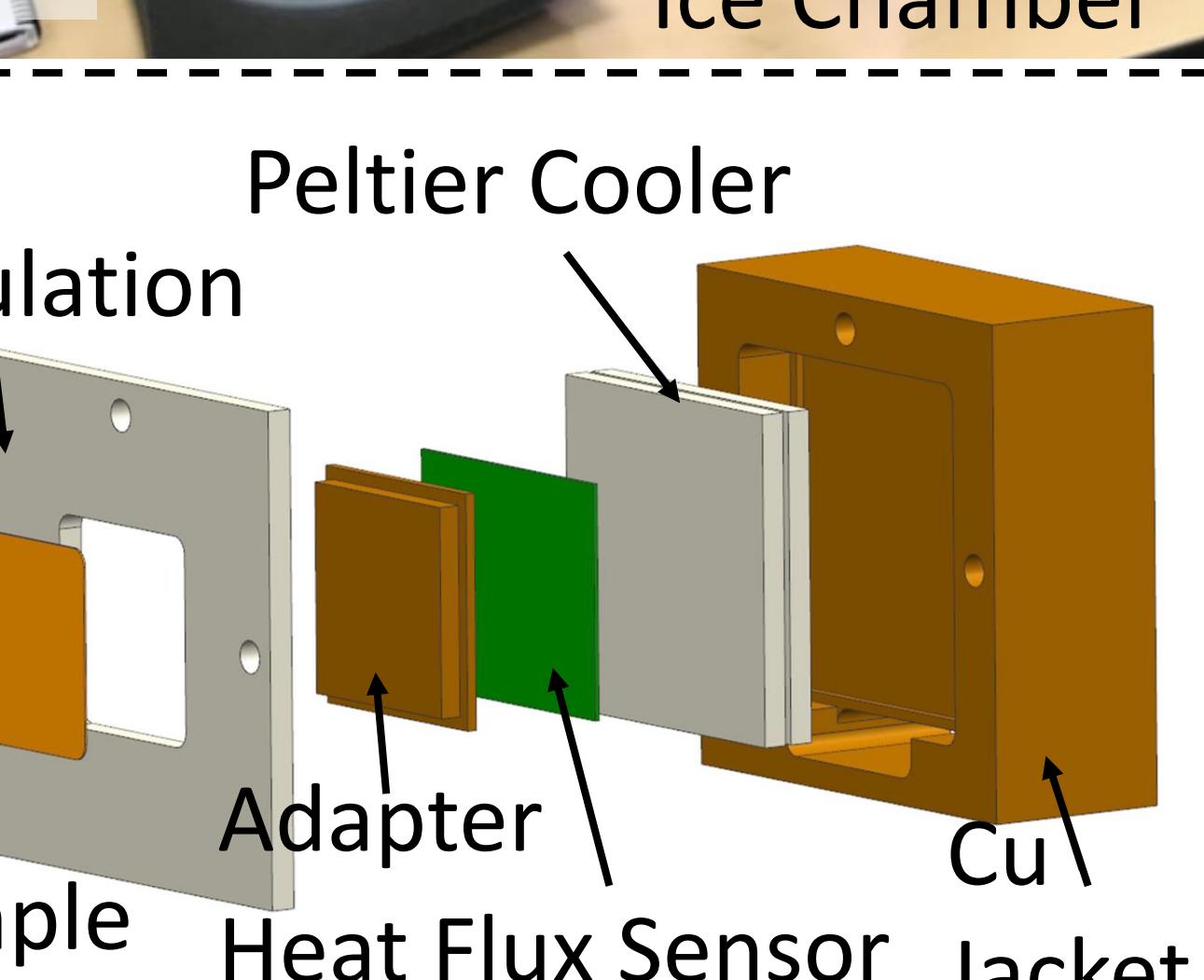
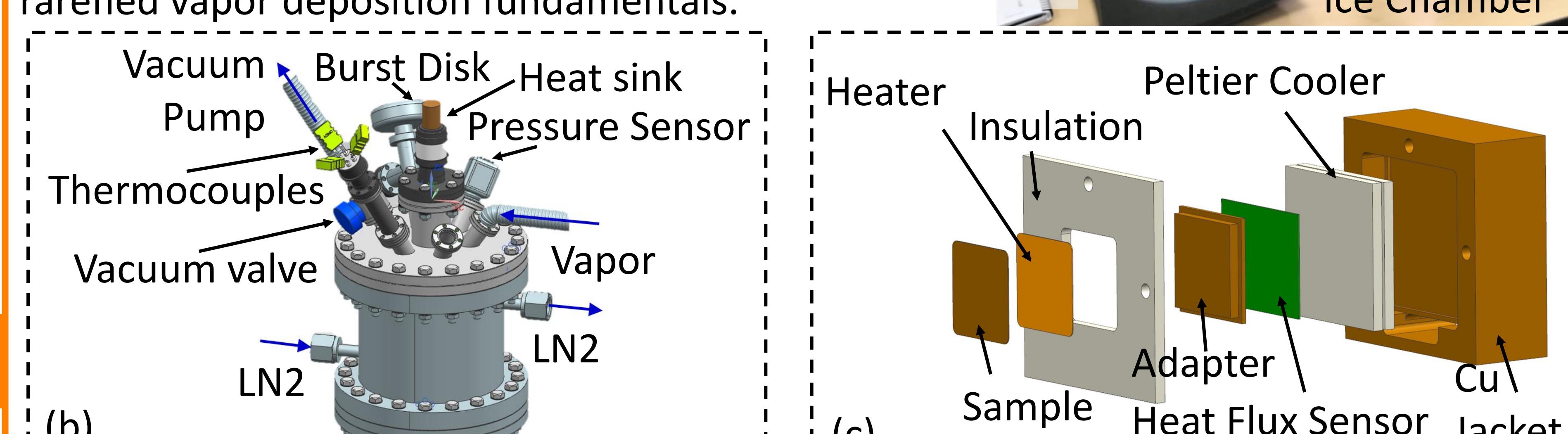
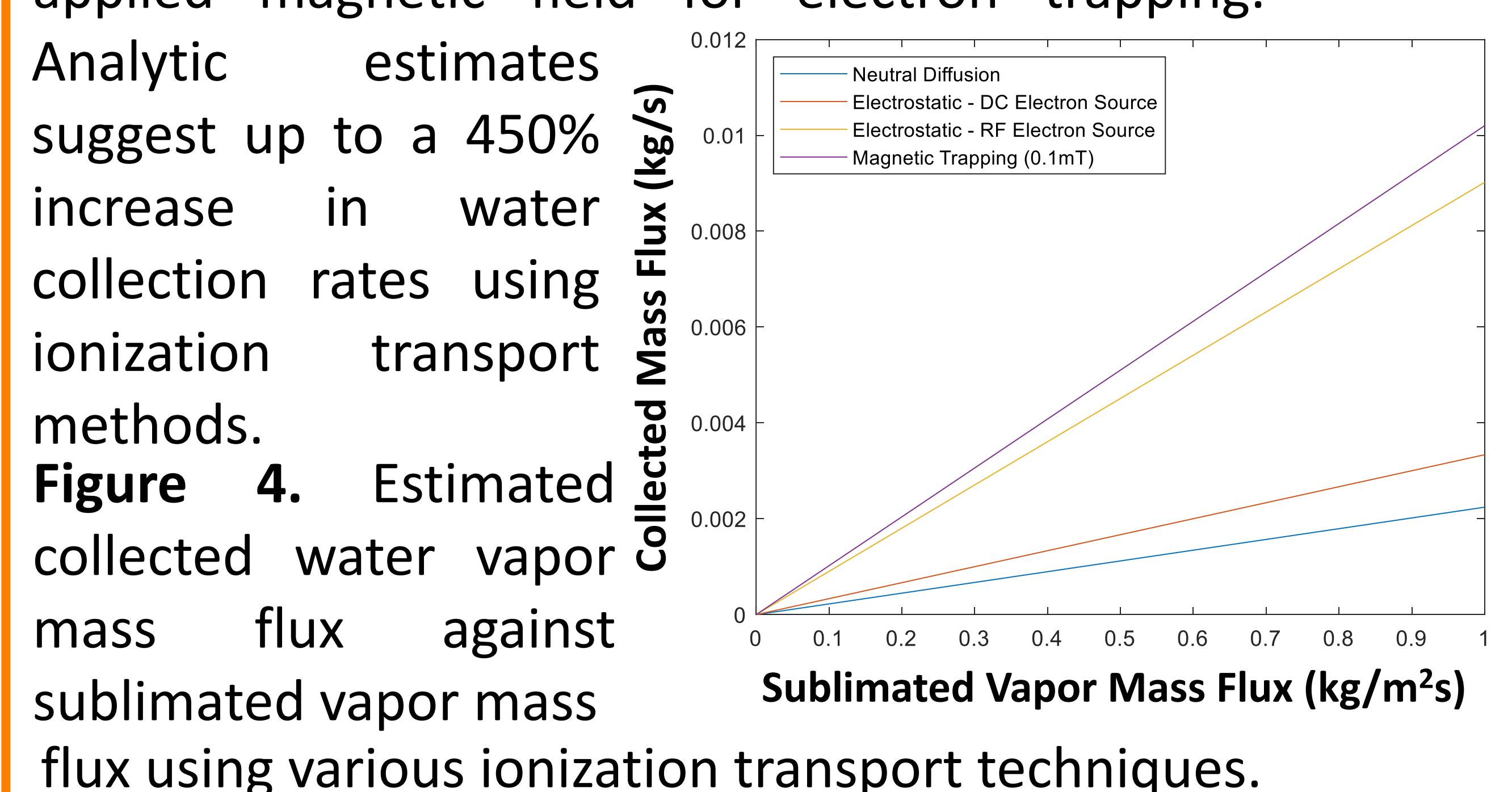


Figure 3. Engineered ice re-capture system: (a) complete assembly including vapor production and ice chambers, (b) ice collection chamber, and (c) cold plate assembly

## Vapor Ionization Rate

Three ionization transport methods (Fig. 4) are considered: (i) a tungsten filament electron emitter, (ii) a radio-frequency plasma source, and (iii) a tungsten filament with applied magnetic field for electron trapping.



## Ice Deposition Rate

The rate of ice deposition for a day on the moon is shown in Fig. 5 based on analytical approximation. It can be seen that a continuous ice deposition results in 4.5 cm thickness whereas, every 30 minutes delamination results in 164 cm of ice accumulation in a day.

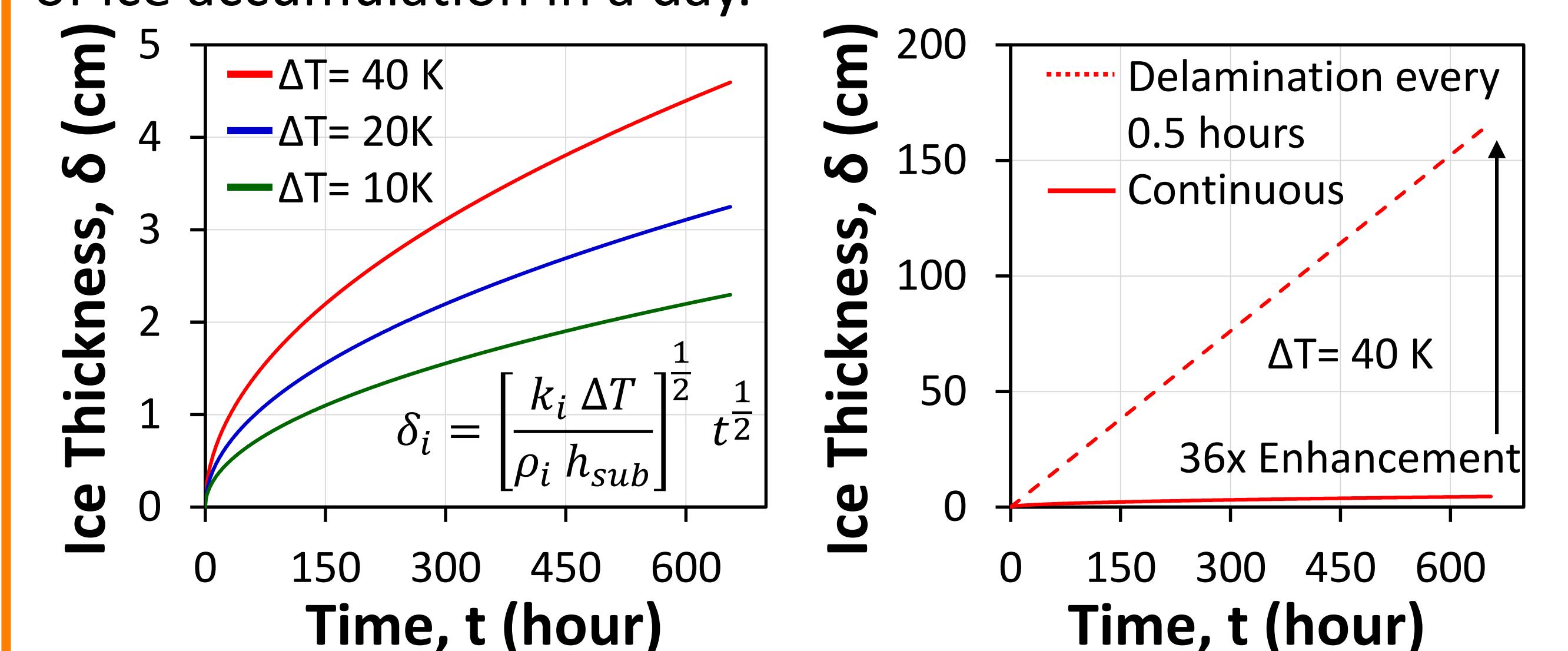


Figure 5. Ice thickness on the cold trap collector plate

## Conclusions

This work aims to demonstrate an efficient high capacity vapor transportation and collection system for advanced lunar thermal mining. Theoretical analysis, design layout and interface definition have been performed. The project is now at the assembly and functionality check stage, and aims to begin testing in the imminent future.