Spaced-based Thermal Systems Applied to Cryo-Environments

The next stage of exploration and utilization of space will require us to operate in extremely cold environments, particularly at cryo-conditions, where the temperature is well below -180 ºC. Such capability will enable us to operate in the Permanently Shadowed Regions (PSRs) of the Moon. In addition, advancing such technology can also provide a multitude of benefits, including the long-term preservation of living cells for safe-keeping and long-duration space travel.

The objective of this paper is to explore the use of cryogenic applications and insulation technologies for small modules/small spacecraft and for lunar applications. Such an effort can facilitate these next stages of exploration and utilization of space. Our main applications is the conceptual design and feasibility study of the power estimate for operating a robotic lunar ark at -180 ºC to -196 ºC in a lunar lava-tubes.

A Lunar Robotic Ark can be a viable method to preserve Earth's rich bio-diversity in an environment that has remained pristine for 3-4 billion years. The lava tubes are expected to be a stable environment where the temperature is at a steady state of -25 ºC. In these conditions we look to provide an estimation of the power required to maintain bio-matter at -196 ºC and seeds at -180 ºC. Operating at these very cold temperatures would sound like a burden, however we can exploit unique phenomenon such as superconductivity and quantum levitation to minimize material to material contact and thus minimize heat transfer through conduction. This approach has helped us to better insulate the cryo-preservation modules that are 25 meters in length and 10 meters in diameter and minimize energy needs.

To further evaluate the feasibility of the lunar robotic ark, we also need to determine the feasibility of transporting cryo-preserved material in modular transport cannisters from Earth to the Moon in at least 5 days. As a first step, we wish to determine feasibility of designing a transport cannister that maintains cryo-temperature for 5 days at LEO. For this we start with a 6U CubeSat that contains cryo-refrigeration system that uses a Stirling engine and insulation to maintain the required temperature.

Last but not least, exploring the PSR's of the Moon is a high-risk high-reward mission to prospect for water ice. There needs to be sufficient water ice on the moon to enable development of a lunar base of any kind. However, PSR conditions present major challenges for operations of conventional landers and rovers. The best option is to provide a distributed low-cost solution. FemtoSats, a platform of less than 100 grams and smaller than a CubeSat can be scattered by the hundreds or thousands into a PSR and help first map the conditions and look for traces of water ice, setting the stage for a more capable rover. We require our FemtoSat to survive in cold temperatures like -230 ºC and operate long enough to map their vicinity and look for clues of water ice on the surface. Together advancement of cryo-technology can have a multitude of benefits in the exploration and utilization of space.