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Author: Dr. Angel Abbud-Madrid
Colorado School of Mines, United States, aabbudma@mines.edu

THERMAL MINING OF WATER ICE IN LUNAR PERMANENTLY SHADOWED REGIONS

Abstract

As on Earth, water is key to the sustainability of space exploration and will underpin most economic activities in space. Water is essential for human life and agriculture and is an effective substance for radiation shielding. But its most valuable use is as rocket propellant in the form of steam, plasma or split into hydrogen and oxygen. Water is truly the oil of space, which will lower transportation costs and enable spaceflight missions not currently possible. The closest source of water ice beyond Earth is the Moon. There is increasing evidence that water ice exists in the Permanently Shadowed Regions (PSR) of its poles. While traditional excavation methods will require heavy machinery operating in extreme environments, direct heating of ice via the Thermal Mining method can reduce cost and weight and eliminate most active components. The Colorado School of Mines has undertaken a study to develop an architecture using Thermal Mining to extract water ice from PSRs and to conduct testing of the effectiveness of direct heat in sublimating ice from regolith simulant samples. This concept uses heat from reflected sunlight directed into the PSRs by heliostats mounted near the crater rim to warm the icy regolith, sublimating the ice and releasing it as vapor. The system consists of a capture tent, secondary optics, and cold trap/ice haulers. The secondary optics receive sunlight from the heliostats and redirects it to the lunar surface. The capture tent encloses the sublimated vapor and directs it to the cold traps mounted to ice hauler vehicles. The production facility generates 1100 tons of propellant per year. A preliminary business case shows positive returns on commercial and government propellant demands assuming an operation of at least 10 years. Tests conducted to date consist on creating an icy regolith simulant, which is then placed in a liquid nitrogen bath inside a vacuum chamber, where a lamp producing one sun of flux illuminates the surface of the sample. After 24 hours, the sample is removed and weighed, with the difference representative of the amount of ice sublimated during the test. The concept study and preliminary tests show that Thermal Mining is applicable and profitable for developing lunar water ice resources. An efficient commercial transportation system and a public-private partnership business model result in much lower costs which will open the Moon and cislunar space to economic development and generate large savings for the Moon-to-Mars program.