BUSINESS CASE FOR MINING PROPELLANT ON THE MOON. George Sowers, Center for Space Resources, Colorado School of Mines, 1310 Maple St., Golden, CO 80401; gsowers@mines.edu

Establishing a permanent human presence in space requires a robust space economy. To be sustainable, a robust space economy must be based on resources found in space and utilized in space. But harnessing space resources requires a significant investment in infrastructure. The key to creating the space economy becomes finding business plans that can develop the infrastructure to utilize space resources, while being profitable at each increment. One of the first economically viable uses of space resources will be propellant derived from water found on the Moon or Near Earth asteroids. This presentation develops a business case for liquid oxygen (LO2), liquid hydrogen (LH2) propellants from water ice extracted from permanently shadowed regions (PSR) near the lunar poles.

Any business case consists of two dimensions, the demand or market dimension and the supply or production dimension. For the business case to be viable, the revenue generated by the demand side of the business must exceed the cost to produce. For lunar derived propellant, the demand side of the business case was provided by United Launch Alliance (ULA) [1]. ULA specified a quantity and price for propellant within cislunar space it would be willing to purchase. ULA derived the quantity and price by analyzing the economics of using that propellant to move commercial satellites from Low earth Orbit (LEO) to geosynchronous orbit (GEO). ULA's requirements were 1100 mT of propellant purchased on the surface of the Moon for $500/kg.

The production side of the business case was developed by a team at the Colorado School of Mines [2]. A system architecture for a lunar mining operation was developed based on a technique called Thermal Mining. This method used sunlight redirected from nearly permanently sunlit regions into the permanently shadowed regions to illuminate and heat the surface of the PSR. The icy regolith is thereby heated, sublimating the water ice. The resulting vapor is captured in dome-like structure and directed into cold traps where it refreezes. The ice is transported to a processing plant where it is purified and split into LO2/LH2 propellant and stored. Masses and costs for each system element were estimated. The total non-recurring cost was estimated to be $2.5B including development, fabrication and delivery to the lunar surface.

For the cash flow analysis, the development and fabrication were assumed to take four years, with one year for deployment and set up. Revenues were collected over a ten-year timeframe and $87M per year was assumed for the operations and maintenance. This scenario generates a 9% internal rate of return with $2B in profit over the life of the project. Another scenario was examined that included an additional propellant demand and investment by NASA through a public private partnership. NASA's additional demand was 100 mT of propellant to be used to fuel lunar landers for ascent from the Moon. The propellant price was kept at $500/kg while NASA's investment in the mining operation was assumed to be $800M. In this case, the IRR increased to 16% with profits topping $3B. NASA's investment resulted in a savings to the taxpayer of $2.45B the first year, and $3.45B each year thereafter versus delivering the propellant from Earth. This is a great example how a public-private partnership can bring significant benefits to both parties.

References

[1] Sowers, G. “A Cislunar Transportation System Fueled by Lunar Resources,” *Space Policy*, 37 (2016) 103-109.

[2] Dreyer, C. B., Sowers, G., and Williams, H., “Ice Mining in Lunar Permanently Shadowed Regions,” *9th Joint Meeting of the Space Resources Roundtable and Planetary and Terrestrial Mining Sciences Symposium*, Golden, Colorado, 2018.