LUNAR ALLOY METAL PRODUCTION PLANT (LAMPP) - NASA 2023 BIG IDEA CHALLENGE. C. B. Dreyer[1], G. F. Sowers[2], P. E. Corwin[3], K. P. Edison[4], G. Jamanca-Lino[5], I. E. Jehn[6] D. P. Purcell[7], V. C. Svaldi[8], A. H. Williams[9], D. P. McConville[10] and L. Sibille[11], [1-9]Colorado School of Mines, Center for Space Resources, 1310 Maple St., GRL 234, Golden, CO 80401, [1]cdreyer@mines.edu, [2]gsowers@mines.edu, [3]pecorwin@mines.edu, [4]kedison@mines.edu, [5]gjamancalino@mines.edu, [6]ijehn@mines.edu, [7]dpurcell@mines.edu, [8]vsvaldi@mines.edu, [9]adamwilliams@mines.edu, [10]Colorado School of Mines, Metallurgical and Materials Engineering, 1301 19th St, Hill Hall, Golden, CO 80401, mcconville@mines.edu, and [11]Southeastern Universities Research Association, sibillel1@gmail.com.

Introduction: In order to support the human exploration of space, the use of local resources, otherwise known as In-Situ Resource Utilization (ISRU), is needed. The Lunar Alloy Metal Production Plant, or LAMPP, is a self-contained, scalable, deployable metal production system designed for use in the lunar environment. LAMPP is based off the nascent technology of Molten Regolith Electrolysis (MRE) which has been proposed as a possible way to extract metals on the lunar surface. MRE passes an electric current through molten regolith to split oxygen from metal oxides to control production rates of oxygen and high-quality metal. The LAMPP system provides enhanced control of MRE output and the ability to extract metal alloys and separate pure metals for further use.

Our group was selected as 1 of 9 universities to receive funding for the 2023 NASA BIG Idea Challenge. Our proposed work will advance the state of MRE technology as several critical technologies must still be developed. Specifically, refractory materials to contain molten regolith, which is known to be highly corrosive and challenging to contain and handle, and also the development of liquid metal flow technology. Beyond developing this technology on Earth, these supporting technologies must also be optimized for the lunar environment, including the impact of dust, vacuum, and 1/6th gravity on molten flow and containment.

Our proposed test and evaluation plan will include the following objectives:

1. Seek to unify what is known about MRE and its associated technologies in the form of a review paper.
2. Test and select various refractory materials as containment for different types of molten regolith of highlands and mare compositions for various qualities like longevity, robustness, and corrosion resistance.
3. Understand and build a reference for how metals flow at high temperatures in a vacuum and how refractory materials and gravity may be impacted.

The ultimate project objective to be presented at the 2023 BIG Idea forum is to produce a preliminary system design that will be conducted as a result of this test and evaluation plan.

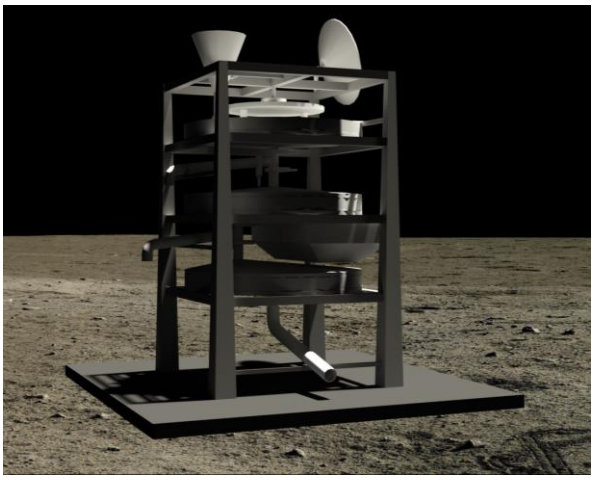

Fig 1: 3D Rendering of the LAMPP System on the Lunar Surface

In space exploration and settlement, ISRU must be leveraged on the Moon to build infrastructure, thereby reducing the need for materials from Earth. Roadways, pathways, foundations, building frames, etc., typically utilize bitumen, concretes, ceramics, and metals as structural building materials on Earth. Similar construction materials will be needed for lunar construction. Metal being a significant structural material with high utilization potential. The LAMPP system has the potential to provide metallurgical-grade alloys that enable the development of sustainable lunar infrastructure. Thus, the extraction of metal is critical to the operation of lunar bases that utilize pressure vessels, piping, power cables, and supporting structures. LAMPP can meet these challenges by deriving metals from the lunar regolith.

References: [1] Allanore, A. et al. (2013). *Nature*, 497(7449). [2] ASM Handbook Committee. (2018). *ASM International* (pp. 1099–1201). [3] ASM Alloy Center Database (2022) *ASM International*. [4] Baker, H. (2018). *Metals Handbook Desk Edition* (pp. 114–121). [5] Benaroya, H. et al. (2013). *Journal of Aerospace Engineering*, 26(1), 152–159. [6] Buratti, B. J., and Johnson, L. L. (2003). *Icarus*, 161(1), 192-197. [7]

Calle, C. I. et al. (n.d.). *NTRS - NASA Technical Reports Server*. [8] Carol, E. (2019) *Space Resources Roundtable*. [9] Chen, G. Z. et al. (2000). *Nature*. [10] Chen, G. Z. (n.d.). *The Vintage News*. [11] Colorado School of Mines. (2018). *SPRS502, Space Systems Engineering*. (pp. 5-6). [12] Curreri, P. A. et al. (2006). *MSFC Independent Research and Development Project No. 5-81*. [13] Grossman, K.D. et al. (2021) *ASCEND 2021* (p. 4019). [14] Harris, D. W. et al. (2022). *Moon to Mars (M2M) Habitation Considerations*. [15] Holt, K. (2022). *Engadget.Com*. [16] Kaufman, J. G. (2018). *Aluminum Science and Technology* (pp. 31–43). [17] Krättli, G., and Schmidt, M. W. (2021). *Contributions to Mineralogy and Petrology*, 176(4), 1-27. [18] Lucey, P. et al. (2006). *Reviews in mineralogy and geochemistry*, 60(1), 83-219. [19] Lomax, B. A. et al. (2020). *Planetary and Space Science*, 180. [20] Morris, R. V. et al. (1983). *Lunar and Planetary Science Conference*, Vol. 14, pp. 528-529. [21] Mueller, R. P., and Sibille, L. (2018). *Materials Science*. [22] NASA. (n.d.). *Significant lunar minerals*. [23] NASA. (2022a). *Moon to Mars Objectives*. [24] NASA. (2022b). *The 2023 Big Idea Challenge Lunar Forge: Producing Metal Products on the Moon. Challenge*. [25] Naser, M. Z. (2019). *Progress in Materials Science* (Vol. 105). [26] Nesse, W. D. (2012). *Oxford Univ. Press*. [27] Radl, A. et al. (2022). *CEAS Space Journal*, 1-11. [28] Sadoway, D. et al. (2019). *Developing a New Space Economy*. [29] Sadoway, D. (2005). *Lunar Regolith Simulant Materials Workshop*. [30] Schlüter, L., and Cowley, A. (2020). *Planetary and Space Science* (Vol. 181). [31] Schreiner, S. et al. (2015a). *8th Symposium on Space Resource Utilization*. [32] Schreiner, S et al. (2016). *Advances in Space Research*, 57(7), 1585–1603. [33] Schwandt, C. et al. (2012). *Planetary and Space Science*, 74(1), 49–56. [34] Shaw, M. G. et al. (2021). *Planetary and Space Science*, 204. [35] Shaw, M. G. et al. (2021). *Lunar Surface-Challenges and Opportunities*. [36] Sibille, L., and Sadoway, D. (2009). *Space Propulsion and Energy Sciences International Forum*. [37] Sibille, L., and Dominguez, J. A. (2012). *Production on the Moon and Mars*. [38] Sirk, A. H. et al. (2010). *ECS Transactions*, 28(6), 367–373. [39] Standish, E. et al. (2010). *Graduate Program in the Department of Materials Science and Engineering, The Ohio State University*. [40] Stefanescu, D. M. et al. (2008). *AIP Conference Proceedings*, 969, 162–169. [41] Taylor, G. J. (2007). *Planetary Science Research Discoveries Report*, 122. [42] Taylor, G. J. (2011). *Planetary Science Research Discoveries*. [43] Taylor, G.J. et al. (2019). *Geochimica et Cosmochimica Acta*. [44] Titz, J. et al. (1990). *Journal of Science & Engineering*. [45] Vai, A. T. et al. (2010). *The Minerals, Metals & Material Society*. [46] Wang, J. (2018). *Aluminum Science and Technology* (pp. 44–79). [47] Weritz, J. (2018). *Aluminum Science and Technology* (pp. 3–30).