ARTEMIS PROGRAM IN-SITU RESOURCE UTILIZATION REQUIREMENTS AND A CRITICAL NEW ROLE FOR COMMERCIAL SURFACE CREW. J. E. Culton[1] and S. Smith[2], [1]Andy Thomas Centre for Space Resources, The University of Adelaide (School of Architecture and Civil Engineering, The University of Adelaide, Adelaide SA 5005 Australia, john.culton@adelaide.edu.au), [2]Andy Thomas Centre for Space Resources, The University of Adelaide (School of Architecture and Civil Engineering, The University of Adelaide, Adelaide SA 5005 Australia, scott.smith@adelaide.edu.au).

Introduction: The U.S. National Aeronautics and Space Administration (NASA), and its many partners, are working to return humans to the Moon as part of the Artemis Program. Unlike the earlier Apollo missions, the Artemis missions will not be "flags and footprints" short-duration sorties, but rather a series of increasingly longer-term missions, concentrated across a few deliberate locations, for the specific purpose of aggregating infrastructure for the ultimate development of a lunar outpost or base [1].

Despite reductions in the cost of access to space, the Artemis Program is estimated to be a USD 93 billion dollar undertaking and so, both government and commercial mission planners, are looking for ways to reduce the overall cost of program activities [2].

One such potential cost saver is to reduce logistics costs by making use of resources available on the Moon to produce expendables (propellant, oxygen, water) and construction materials in-situ. With the government as a potential anchor customer, multiple commercial ventures are therefore aiming to develop the plans and infrastructure to provide these basic mission consumables for sale at multiple destinations within cis-lunar space.

While a human presence on the lunar surface is central to the Artemis Program, the same cannot be said of commercial efforts to provide in-situ derived resource products. Proponents of an all-robotic workforce cite the significant safety, technical, and resultant financial challenges associated with sustained human presence on the lunar surface, and on this basis, proposals for the construction and operation of lunar surface resource facilities are being produced on the assumption of an all-robotic workforce [3].

Discussion: Mining, at scale, in the lunar environment will be extremely challenging. Comparisons of the relative environments endured by equipment at the terrestrial "coal face" vs that on the Moon, suggest at least an order of magnitude increase in destructive capability when interacting with lunar regolith [4].

Within the terrestrial mining industry, certain mechanical breakdown pathways are well understood. The chief considerations regard the hardness of the material being mined and the resultant dust created in the process [5]. On Earth, these two factors often oppose each other: harder material produces less dust. However, on the Moon, billions of years of weathering have produced a thick multi-meter deep layer of regolith that cant be avoided and is present in quantities that exceed operational terrestrial mines [6].

The expected result is that industrial equipment on the Moon will face challenges that terrestrial miners, who operate in a much more benign environment, still can not solve as even today mining equipment suffers breakdown rates exceeding 20%, especially for equipment that is involved in kinetic interactions with the targeted material such as excavators and loaders [7].

Given the resultant robotic workforce production metrics needed to achieve aspirational resource supply goals as suggested by NASA's Space Technology Mission Directorate, aspiring lunar resource providers should anticipate an indispensable need for human maintenance technicians to rescue and repair the industrial robotics put into service on the Moon [8].

Conclusion: Given humanities 42,000 years of collective mining experience within the comparatively benign terrestrial environment and the significant resultant equipment breakdown rates still experienced within the modern mining industry, a new requirement for aspiring commercial lunar resource providers is suggested: that of on-site human maintenance technicians who, much like their terrestrial industry counterparts, work full-time keeping the mining equipment operational.

References: [1] "NASA's Lunar Exploration Program Overview." Washington D.C.: NASA [2] NASA OIG 2021a . "NASA'S Management of the ARTEMIS Missions." Washington D.C.: NASA OIG. IG-22-003 (A-20-008-01). [3] Kornuta et al, 2019. "Commercial lunar propellant architecture: a collaborative study of lunar propellant production." REACH. [4] Mukherjee, S. 2011. "Applied mineralogy : applications in industry and environment." Springer Science and Business Media. Dordrecht: Springer. [5] Ho, M., and M. Hodkiewicz. 2013. "Factors That Influence Failure Behaviour and Remaining Useful Life of Mining Equipment Components." *Advances in Mechanical Engineering*, 5, p.913048. [6] Gaier, J.R. 2005. "The Effects of Lunar Dust on EVA Systems During the Apollo Missions." Glenn Research Center, Cleveland, Ohio: NASA. NASA/TM—2005-213610. [7] Samanta, B., Sarkar, B. and Mukherjee, S.K. 2001. "Reliability cen-

tred maintenance (RCM) for heavy earth-moving machinery in an open cast coal mine." The CIM Bulletin. 94. 104-108. [8] NASA 2023. Space Technology Mission Directorate Strategic Framework. "Excavation, Construction, and Outfitting (ECO) Envisioned Future Priorities".