

Metal Manufacturing on Lunar Surface – from Alloys to Components

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Abstract: Keystone Synergistic Enterprises, LLC is a provider of large format metal additive manufacturing (AM), having extensive experience in metal working and materials analysis of aerospace alloys including subscale channel wall rocket nozzle AM for NASA MSFC and Wire Metal AM in-situ defect detection for NASA STMD. Keystone has been an active member of LSIC and aims to bridge the critical gaps of in-situ metal components manufacturing and metal feedstock supply for a sustainable lunar base infrastructure development. To fulfill these aims, Keystone plans to undertake a capability development of manufacturing metal components such as construction structural elements (metal beams, columns), construction vehicle components (metal hulls, trusses), weld wire and power transmission cables etc. – all based on lunar surface-based resources. To develop the groundwork for this, Keystone will team up with QuesTek Innovations LLC and perform extensive study and analysis to narrow down feasible metal alloys to be derived from lunar regolith, followed by AM parts production.

QuesTek Innovations is a recognized global leader in Integrated Computational Materials Engineering (ICME) technologies and has the expertise and resources to efficiently create new materials meeting mission-specific properties. QuesTek uses its proprietary Materials by Design® methodology to rapidly design, test, characterize, qualify and insert new high-performance materials into industrial use. To address the materials needs in LSIC's ISRU and E&C endeavors, QuesTek proposes the following – (1) a wide range of existing earth-based construction alloys (steels, aluminum-, titanium-alloys, etc.) will be surveyed and assessed to identify potential manufacturability on the lunar surface using resources extracted from lunar regolith. Information regarding composition and microstructure of lunar regolith provided by the ISRU team will be utilized. And (2) new lunar-based materials and processes may need to be designed/developed in order to achieve optimized materials performance when manufactured using lunar regolith. QuesTek will leverage its expertise in understanding and modeling materials' key process-structure-property (PSP) relationships to design and develop novel materials compositions and processes, that are

tailored to be manufactured from the specific lunar regolith resources.

Keystone proposes to use this database of relevant alloys and the PSP relationships and ultimately derive wire feedstock (collaborating with ISRU and wire supplier partners) which will be used for further manufacturing the necessary lunar base infrastructure elements using arc and laser wire metal AM processes. The reason for using wire is for easier feedstock management and safety compared to powder. Keystone currently houses two robotic Wire Arc metal AM cells and planning to establish an in-house Laser Wire metal AM cell. These in-situ defect detection and identification-capable AM cells will be used for earth-based demonstrations and developing early stage coupon and component build testing. The Wire Arc system is used for high deposition rate, large parts AM, and the Laser Wire system is used for smaller parts AM, channel wall heat exchangers' closeout deposition and additively performing near net finishing of the Wire Arc AM parts. A roadmap will be prepared for evolving the technologies for lunar environment considering lower gravity, vacuum, wide temperature swing, low weight, low energy, high autonomy and in-situ defect repair requirements. Collaboration is planned to include manufacturers of lunar construction vehicles to address vehicle component manufacturing on the moon. Overall, Keystone envisions to synergistically develop a lunar resource-based metal manufacturing facility contributing to a sustainable lunar base establishment.



Fig 1. (Top-Left & Bottom) Large metal components manufactured by Keystone using in-house robotic Wire Arc Metal AM cell. (Top-Right) Channel wall nozzle closed out using Laser Wire AM.