I/UCRC Executive Summary - Project Synopsis	**Date**: April 2020

Center/Site: CANFSA/Colorado School of Mines

Tracking No.:30-L: Mechanisms of Grain Refinement in Laser Powder Bed Fusion of In-Situ Metal Matrix Composite 6061 Aluminum Alloys	**Phone:** (843) 618-7968	**E-mail:** chloejohnson@mymail.mines.edu

Center/Site Director: CANFSA/M. Kaufman/P. Collins/A. Clarke	**Type: (Continuing)**
Project Leader: Chloe Johnson	**Proposed Budget**: $240,000

Project Description: The number of useful alloys for additive manufacturing (AM) is still limited, especially aluminum alloy systems, which are prone to columnar grain growth and hot cracking. Inoculation presents a method to not only induce the columnar to equiaxed transition, but also refine grain size, which can eliminate hot cracking and reduce anisotropy. While mechanisms of grain refinement in inoculated aluminum alloys are well understood in traditional casting techniques, opportunity exists to understand these mechanisms in the context of rapid solidification conditions imposed by AM. This project proposes to explore grain refinement mechanisms in inoculated Al 6061 alloys during AM processing via laser powder bed fusion (LPBF).

Experimental plan: The Interdependence Model, which evaluates the effects of various conditions (e.g. solute, nucleant type, etc.) on grain size in inoculated aluminum alloys, will be used to investigate mechanisms controlling grain refinement under rapid solidification conditions. Contributions such as solute content, nucleant potency, and nucleant site density will be considered.

Related work elsewhere: Extensive work has been done on inoculated aluminum alloys in traditional casting. However, only recently has rapid solidification conditions, such as those seen in AM, been considered. While some studies have addressed inoculation in AM, mechanistic understanding of grain refinement for different alloying strategies remains to be understood.

How this project is different: This project seeks to better understand the mechanisms driving grain refinement in inoculated aluminum alloys during AM. It will also explore the application of the Interdependence Model to solidification conditions beyond casting. This will be accomplished by parameterization of the factors considered in this model with solidification conditions by *in-situ* radiography during solidification measurements. This project will also extend our understanding of simulated additive manufacturing to actual AM builds.

Milestones for the current proposed year: Post-mortem imaging and measurements of various parameters will be performed on samples generated during *in-situ* radiography experiments. These parameters will inform the Interdependence Model to evaluate the effects of alloying, inoculant, and solidification conditions on grain refinement mechanisms in Al 6061 alloys.

Deliverables for the current proposed year: *In-situ* experiments have been performed and post-mortem analysis of microstructure is underway. The parameters measured in post-mortem imaging and analysis of *in-situ* radiography data (i.e. solidification velocity, grain size, etc.) will be used to adjust parameters in the Interdependence Model to evaluate grain refinement during rapid solidification of aluminum alloys.

How the project may be transformative and/or benefit society: Understanding grain refinement mechanisms in aluminum alloys will aid in alloy design, as well as an improved model that can be used to evaluate other inoculated alloy systems.

Research areas of expertise needed for project success: Solidification; microstructural development; *in-situ* imaging; advanced electron microscopy; materials processing; additive manufacturing.

Potential Member Company Benefits: The fundamental knowledge gained from this project will be applicable to aluminum and other metallic alloys to help predict and control final microstructures and properties, as well as aid in alloy design for processes like additive manufacturing.

Progress to Date: Two rounds of *in-situ* experiments have been performed on Al 6061 and 6061 inoculated alloys at the Advanced Photon Source at Argonne National Laboratory. Measurements of grain size and imaging processing have been performed. AM builds have also been generated to compare the single raster melts produced in these experiments to full-sized parts.

Estimated Start Date: Fall 2017	**Estimated Knowledge Transfer Date**: Spring 2021

The Executive Summary is used by corporate stakeholders in evaluating the value of their leveraged investment in the center and its projects. It also enables stakeholders to discuss and decide on the projects that provide value to their respective organizations. **Ideally, the tool is completed and shared in advance of IAB meetings to help enable rational decision making.**