I/UCRC Executive Summary - Project Synopsis	**Date**: October 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**: $240-320K, Leveraged

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 refine grains, which can eliminate hot cracking and reduce anisotropy. While proof of concept studies have proven inoculation in aluminum alloys for AM to be viable, the grain refinement mechanisms in these alloys are not fully understood. This project proposes to explore grain refinement mechanisms in inoculated Al 6061 alloys during AM processing via laser powder bed fusion (LPBF).

Experimental plan: A6061-RAM alloys, developed for AM by Elementum 3D, will be investigated using extensive in-situ and ex-situ characterization to understand how solidification conditions and composition of these alloys (i.e. the amount of particles added to the initial alloy powder) impact grain refinement.

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 limited 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, as well as investigate an in-situ inoculated aluminum alloy never before studied. This will be done by coupling novel in-situ characterization with complementary ex-situ characterization to understand how solidification conditions and initial particle concentration in the alloy powder impact microstructural development in these alloys during AM.

Milestones for the current proposed year: Post-mortem characterization of samples generated during in-situ experiments will be correlated to measured solidification velocities and modeled thermal gradients using Flow 3D to understand how solidification conditions impact grain refinement in these alloys. Characterization of AM builds of various starting particle contents will also be performed to consider the impact of particle content on grain refinement.

Deliverables for the current proposed year: *In-situ* experiments have been performed and post-mortem analyses of microstructures is underway. Microstructural observations in these samples will be linked to velocity measurements and thermal gradient modeling with Flow 3D, both of which are currently being performed, but have yet to be correlated.

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 provide strategies 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 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 A6061-RAM alloys at the Advanced Photon Source at Argonne National Laboratory. Half or more of these samples have been characterized and found to achieve grain refinement, with little to no dependence on solidification conditions. Some investigation into types of particles that form in at least one starting particle concentration of A6061-RAM has been initiated.

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.**