I/UCRC Executive Summary - Project Synopsis	**Date**: October 2021

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**: $320,000

Project Description: The number of useful alloys for additive manufacturing (AM) is still limited, especially regarding aluminum alloys, which are prone to columnar grain growth and solidification cracking. Inoculation presents a method to not only cause grain refinement, but also reduce solidification cracking. 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 reactive additive manufacturing 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 in these alloys.

Related work elsewhere: Extensive work has been done on inoculated aluminum alloys in traditional casting. However, only recently have 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, as well as investigate an in-situ inoculated aluminum alloy never before studied. This will be done by coupling novel in-situ and ex-situ characterization to understand how solidification conditions and initial particle concentrations in the alloy powder impact microstructural development during AM.

Milestones for the current proposed year: Identification of various particles will be completed for alloys containing a variety of different starting reactive particle contents and correlated to other findings to investigate grain refinement mechanisms for each alloy during AM processing. Thesis writing and defense is proposed for the end of 2021/beginning of 2022.

Deliverables for the current proposed year: A study focusing on heat treatment of A6061-RAM alloys was completed and is under review for publishing. Thermal gradient modeling for investigating the impact of solidification conditions on refinement was also completed. Experiments to identify phases in alloys containing various starting particle contents has been partially completed, particularly XRD and SEM investigations of each alloy, with TEM having been performed on Al-Ti and A6061-RAM(Ti).

How the project may be transformative and/or benefit society: Understanding grain refinement mechanisms in aluminum alloys will aid in alloy design, including approaches 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: *In-situ* experiments have been performed on Al 6061 and A6061-RAM alloys at the Advanced Photon Source at Argonne National Laboratory. These samples have been characterized and solidification velocities have been extracted from the in-situ radiography. A study looking at the impact of heat treatment on microstructural development has been performed and completed. Investigation into the particles present, and the role in grain refinement, has been started, with SEM and XRD being completed for each alloy and TEM analysis partially completed and still underway.

Estimated Start Date: Fall 2017	**Estimated Knowledge Transfer Date**: Spring 2022

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.**