I/UCRC Executive Summary - Project Synopsis		**Date**: October 2020
Center/Site: CANFSA/Colorado School of Mines		
Tracking No.:36D-L: Characterizing Additively Manufactured Inconel 718/738	**Phone:** (210)-315-5547	**E-mail:** jeremy.shin@mymail.mines.edu
Center/Site Director: M. Kaufman/P. Collins/A. Clarke		**Type: (Continuing)**
Project Leader: Jeremy Shin		**Proposed Budget**: $240-320K, Leveraged

Project Description: This project is a part of a Multidisciplinary University Research Initiative (MURI) project funded by the Office of Naval Research (ONR) that will focus on additively manufactured (AM) samples of Inconel 718 and 738. The goal is to analyze how microstructural development, texture, and mechanical anisotropy evolve from the layer-by-layer AM build process, and to reveal control mechanisms with respect to different build parameters. Experiments will be done at the Advanced Photon Source (APS) at Argonne National Laboratory (ANL) to simulate the melt pool of the laser powder bed fusion AM process and solidification. From these results, solidification behavior will be extracted and related to microstructural evolution through post-mortem microscopy. Samples from the Manufacturing Demonstration Facility (MDF) at Oak Ridge National Laboratory (ORNL) will also be characterized to clarify the role of scan strategy on microstructural and mechanical anisotropy. This work is of interest to the aerospace sector, as Ni-based superalloys are desirable for their creep behavior and oxidation resistance, making them excellent candidates for gas turbines and other internal propulsion parts. Inconel 718 and 738 are already heavily used alloys in industry, and understanding the differences between microstructures produced by AM and conventional methods will lead to the manufacturing of improved parts with improved microstructures and properties.

Experimental plan: Simulated AM at the APS will be conducted with both spot and raster melts. *In-situ* radiography data and post-mortem electron microscopy will be used to identify a hot-cracking regime for Inconel 738. Neutron diffraction measurements will be performed on Inconel 718 to analyze texture. Mechanical testing may be performed to understand elastic modulus changes observed after AM, as compared to that observed after wrought processing.

Related work elsewhere: Experiments will be carried out at the APS for *in-situ* radiography of AM melt pools and solidification behavior. There are plans in the near future to collaborate with Los Alamos National Laboratory (LANL) to evaluate crystallographic texture from neutron diffraction.

How this project is different: This project aims to quantify the power density ranges for AM production of Inconel 738 that avoid hot cracking. Another goal is to study the changes in texture and elastic modulus of Inconel 718 by adding inoculants.

Milestones for the current proposed year: Completion of post-mortem metallography and electron microscopy on Inconel 738 samples from the APS 2020 run. Organize neutron diffraction experiments at LANL on as-built Inconel 718 samples with and without inoculants and other Ni alloys.

Deliverables for the current proposed year: A peer-reviewed publication on AM Inconel 738 hot cracking, texture analysis of Inconel 718 with inoculants, and summary reports/presentations to the project sponsor, the Office of Naval Research.

How the project may be transformative and/or benefit society: An important benefit of AM is to eliminate processing steps to save resources and costs during production. The microstructural evolution of as-built AM parts is poorly defined, as thermal cycling and large thermal gradients from the build process differ from legacy manufacturing techniques such as casting and forging. Therefore, it is important to understand fundamental materials science phenomena through *in-situ* and *ex-situ* experiments to better understand the end-result microstructures and material properties.

Research areas of expertise needed for project success: Solidification, neutron diffraction, crystallographic texture, crystallography, and physical metallurgy of Ni-based superalloys.

Potential Member Company Benefits: This project is of direct interest to DoD and CANFSA members in the aerospace and power industries. With a deeper understanding of the processing-microstructure-property relationships, AM can be more broadly applied to high temperature structural components, potentially leading to more efficient and lower cost designs.

Progress to Date: Literature review for hot cracking in Inconel 738 and the CET in Inconel 718 is ongoing. Experiments at the APS were completed in February 2020. Top-down imaging of the melt pool surfaces showing cracking events and interesting flow patterns was done in summer 2020. Proposal preparation for texture experiments at LANL are in progress.

Estimated Start Date: Fall 2019	**Estimated Knowledge Transfer Date**: Spring 2023

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.**