I/UCRC Executive Summary - Project Synopsis	**Date**: April 2022
Center/Site: CANFSA/Colorado School of Mines	
Tracking No.: 56-L: Thermomechanical Processing of Refractory Multi-Principal Element Alloys for Ultrahigh Temperature Performance	**E-mail :** abalzac@mines.edu **Phone :** (978) 760–9135
Center/Site Director: CANFSA/M. Kaufman/P. Collins/A. Clarke	**Type: (Continuing)**
Project Leader: Adira Balzac	**Proposed Budget**: $320K (Leveraged)
Project Description: Refractory multi-principal element alloys (RMPEAs) maintain their strength in ultrahigh temperature applications and can operate without the need for extensive coolant systems or coatings that reduce efficiency. RMPEAs that can meet operating temperature and strength needs have the potential to increase efficiency and operating lifetime of high-temperature components over modern nickel-based superalloys.	
Experimental plan: RMPEAs will be selected based on thermodynamic, kinetic, and solid solution strengthening models. The selected alloys will be produced at the Colorado School of Mines. The as-cast microstructures will be characterized and a thermomechanical processing technique for controlling the microstructure will be developed. The effect of carbides and oxides for precipitation strengthening will also be investigated.	
Related work elsewhere: Previous studies have developed predictive solid solution strengthening models for MPEAs. Collaboration with UCSB and Johns Hopkins University will include modeling conducted at UCSB to predict dislocation dynamics and mechanical and creep tests being conducted at JHU. Previous work has been done to characterize the thermomechanical properties of various compositions, but only at temperatures up to ~1000 °C.	
How this project is different: RMPEAs have not yet been extensively studied, and many studies focus on characterizing as-cast microstructures. This project will focus on identifying deformation mechanisms in MPEAs, developing thermomechanical processing methods to control microstructure, and developing processing maps. The effects of interstitial carbon and oxygen will also be investigated as a potential means for controlling microstructure and properties.	
Milestones for the current proposed year: Identify alloys and compositions of interest; develop methods for producing alloys reliably; characterize initial alloy microstructures and thermomechanical properties.	
Deliverables for the current proposed year: Selection of alloys for further investigation, investigating as-cast alloy microstructures across composition space and temperature, thermomechanical processing and microstructure characterization of selected RMPEAs, and presenting at MS&T on phase equilibria of NbTaTi and NbTiZr ternaries.	
How the project may be transformative and/or benefit society: RMPEAs have the potential to replace modern nickel-based superalloys in ultrahigh temperature applications such as gas turbine engines. RMPEAs can improve engine efficiencies and component operational lifetimes.	
Research areas of expertise needed for project success: Arc melting, SEM for EBSD, TEM, XRD, Gleeble thermomechanical testing.	
Potential Member Company Benefits: Development of alloys that can withstand extended operation at ultra-high temperatures and deeper understanding of the principles behind MPEAs.	
Progress to Date: Gaps in literature data for refractory ternary alloys NbTaTi and NbTiZr that limit CALPHAD simulations have been identified. Solid solution strengthening models and CALPHAD phase equilibrium simulations have been used to select four off-equimolar ternary compositions and corresponding four equimolar ternary compositions that are predicted to have stable single-phase BCC structures and high athermal yield stress for further investigation.	
Estimated Start Date: Fall 2021	**Estimated Knowledge Transfer Date**: Spring 2025

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.**