I/UCRC Executive Summary - Project Synopsis	**Date**: March 2019

Center/Site: **CANFSA/Colorado School of Mines**

Tracking No.: 33a-L: In-situ Studies of Strain Rate Effects on Phase Transformations and Microstructural Evolution in β-Titanium Alloys	**Phone :** (720) 272-9125	**E-mail :** bellyson@mymail.mines.edu

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

Project Description: Here we will investigate the deformation mechanisms and microstructural evolution in metastable β-titanium alloys as a function of deformation pathway, processing and composition to formulate an alloy design methodology. Specifically, transformation and twinning induced plasticity (TRIP & TWIP) effects are the main focus of this project, as they allow for high work-hardening and uniform elongation, without compromising strength. These alloys present potential blast and crash resistance, due to high absorbed-energy, as well as increased formability due to high uniform elongation.

Experimental plan: Multiple alloys of varying compositions will be mechanically tested in different microstructural states during quasi-static and dynamic deformation. Characterization of the samples will occur before, after and during deformation with state-of-the-art techniques to understand the dependencies of TRIP and TWIP effects on intrinsic and extrinsic factors. This understanding will be used to inform the design methodology by means of analytical and numerical methods.

Related work elsewhere: The high-rate compressive and tensile deformation behavior of metastable β-titanium alloys is sparse to non-existent in the literature. Limited studies have started to explore the role of strain rate on compressive behavior, but not at high rates or in tension.

How this project is different: Concurrent efforts by other groups have only utilized existing design methods to develop new alloys. This project is the first to propose a full-cycle study with the aim of producing and validating a design methodology aimed at specific applications, such as blast resistance.

Milestones for the current proposed year: Comparison of the TRIP/TWIP behavior and work hardening of metastable β-Titanium alloys in compression and tension as a function of strain rate and β grain size is planned. High-rate in-situ and post-mortem tests (split-Hopkinson bar) of Ti-1023 and Ti-15Mo are planned to gain understanding of the strain-rate dependencies of TRIP/TWIP deformation mechanisms. Fine-scale characterization of deformed microstructures is also planned to understand the dominant deformation mechanisms during dynamic testing.

Deliverables for the current proposed year: The role of athermal ω phase on the yield stress and work hardening rate of Ti-1023 and Ti-15Mo will be explored. A mechanistic model of deformation mechanisms (TRIP/TWIP/slip) and interactions between different phases as a function of initial microstructure will be explored for the alloys being tested, i.e. Ti-1023and Ti-15Mo.

How the project may be transformative and/or benefit society: Lightweight, blast resistant armor and crash-resistance structures are a major concern for defense applications, while increased formability will greatly extend the applicability of these alloys to more complex, plastically formed parts.

Research areas of expertise needed for project success: Mechanical testing and microstructural characterization (optical, advanced electron microscopy, x-ray diffraction), in-situ studies during deformation at national user facilities, analytical and numerical modeling of materials, alloy design and material processing and fabrication.

Potential Member Company Benefits: The benefits will be threefold: First, the design methodology will permit the mechanical behavior of novel alloys to be tailored to specific applications. Second, increased formability of alloys studied would extend potential applications. Third, greater understanding of TRIP & TWIP effects will lead to better manufacturability and improved end-user design tolerances. It is anticipated that these results will be of interest to CANFSA's members interested in aerospace and defense applications.

Progress to Date: Quasi-static compressive and tensile studies of Ti-1023 are complete and effect of grain size on yield stress and work hardening are being analyzed. Transmission electron microscopy of interrupted strain tensile tests are underway to understand to microstructural evolution in the early stages of plastic deformation of Ti-1023. High-rate testing in compression and tension were completed using a Kolsky bar setup at the Advanced Photon Source (APS) in Argonne, Il. These tests were completed on Ti-1023, Ti-15Mo and medium entropy alloys Ti-35Zr-10Nb and equimolar TiZrNb. Data analysis of these tests are underway.	
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.**