I/UCRC Executive Summary - Project Synopsis		**Date**: March 2, 2020
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	**Phone :** (720) 272 -9125	**E-mail : :** bellyson@mymail.mines.edu
Center/Site Director: M. Kaufman/P. Collins/A. Clarke		**Type: (Continuing)**
Project Leader: Benjamin Ellyson		**Proposed Budget**: $ 240K, Leveraged

Project Description: The deformation mechanisms and microstructural evolution in metastable β-titanium alloys as a function of strain rate, microstructural condition, and alloying will be studied to formulate alloy design methodologies that promote desirable strength/ductility combinations. 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 at quasi-static, intermediate, and high strain rates. Microstructural characterization will be performed during and after deformation to understand the dependencies of TRIP and TWIP effects on intrinsic and extrinsic factors. This understanding will be used to inform alloy, microstructure, and property design methodologies 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 compression, 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: Characterization of TRIP and TWIP effects in Ti-1023 and Ti-15Mo and dependencies on strain rate, temperature, strain state, prior processing and microstructure (Feb 2019). In-situ characterization of microstructural evolution during high rate deformation of both alloys (Dec 2018). In-situ study of TRIP and TWIP effects of Ti-15Mo by TEM (May 2019).

Deliverables for the current proposed year: Model describing dependencies of TWIP and TRIP in Ti-1023 and Ti-15Mo as a function of heat-treatment and deformation conditions, specifically compression, tension and high-rate deformation. Mechanical testing and in-situ and post-mortem characterization will be performed this year.

How the project may be transformative and/or benefit society: Lightweight, blast resistant armor and crash-resistant structural components are a major concern for defense applications, while increased formability will greatly extend the applicability of these alloys for the manufacture of 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 material modeling, alloy design, 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 for specific applications. Second, increased formability of the alloys studied would extend potential applications. Third, greater understanding of TRIP and 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 and the DoD.

Progress to Date: Significant effort has been aimed at understanding the low-temperature aging response of TRIP Ti-1023, as it has been found to strongly impact yield stress in the solution treated condition, even at room temperature, which has implications for the long-term stability of these alloys. Tensile testing at multiple strain rates, ranging from 10^{-3} to 10^{0} s^{-1} has been successfully accomplished;

these microstructures are currently being characterized. TWIP Ti-15Mo is also undergoing a similar study in the as-quenched state only. Additionally, in-situ x-ray imaging during high-rate Kolsky bar tensile testing has been performed at Sector 32-ID at the Advanced Photon Source (APS) at Argonne National Laboratory in Feb 2020. Quasi-static, in-situ testing was also planned in March 2020, but these experiments have been postponed due to COVID-19 restrictions. Work planned for the near future includes possible in-situ tensile testing at quasi-static strain rates in the transmission electron microscope at Lawrence Livermore National Laboratory. In-situ quasi-static deformation experiments at Sector 1-ID at the APS and bulk Klosky bar testing at Los Alamos National Laboratory are also planned. In the short term, in-situ testing data from the APS experiments in Feb. 2020 will be processed.	
Estimated Start Date: Fall 2017	**Estimated Knowledge Transfer Date**: Spring 2021